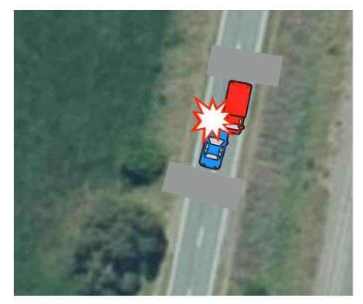

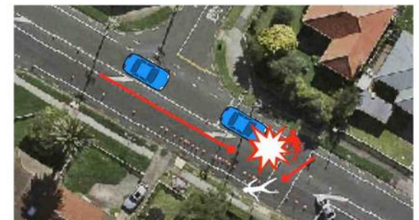

# CONTRIBUTING FACTORS TO FATAL CRASHES:

## A SAFE SYSTEM ANALYSIS OF CONTEXTUAL FACTORS

Sam Wrightson | Hamish Mackie | Rebecca Luther
Julia Mackie | Emily Mackie | Maxwell Wrightson

2 APRIL 2026

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**Authorship:** This document was written by Sam Wrightson and Hamish Mackie with contribution from others. For further information, please contact Hamish Mackie at hamish@mackieresearch.co.nz.

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**Mackie Research physical and postal address**
1 Albert St,
Auckland 1010

www.mackieresearch.co.nz

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## Project Outline

Road deaths in New Zealand have reduced significantly since the mid-1980s, but despite fluctuations have remained stubbornly high at around 300-350 deaths per year for the past 10 years. A continued understanding of the elements the most severe crashes is needed to inform evidence-based actions that have the greatest chance of reducing them.

This research aimed to build on, and update, previous work investigating the contributing factors and nature of fatal crashes using a Safe System approach. The analysis was designed to allow comparison to previous and overseas work to assess changes over time as societal and policy developments have occurred.

The Safe System approach focusses on both deaths and serious injuries. However, serious injury data in New Zealand covers a large range of situations and severities with no distinction between relatively minor medical treatment and potentially life changing injuries. Given the resources available, a focus on fatal crashes was chosen to better understand the most severe crashes within a relatively homogeneous dataset.

Specifically, this project addresses the following research questions:

1. What are the Safe System determinants of fatal road crashes in New Zealand, as defined by previous research?
2. What proportion of crashes result from everyday mistakes and 'system failures', compared with crashes where illegal or reckless/extreme behaviour was involved?
3. What are the implications of the findings for policy, and practice?

## Research Approach

A brief literature scan was conducted to identify similar studies to allow the comparison of findings, and to aid in the development of the Safe System analysis framework.

Two hundred fatal crashes from across New Zealand in 2024 were randomly sampled, representing 80% of all crashes that year. Sampling was carried out separately for two cohorts 'light-vehicle-only' and 'all-other' crashes, each consisting of 100 crashes. A Safe System framework guided the analysis, with specified contributing factors triggering each pillar- roads and roadsides, speed environment, vehicles, and users. Descriptive statistics were produced for the full sample and each crash cohort.

Crashes were also classified based on the presence of different road user behaviours in the crash circumstances. The definition of each of these classifications is provided below:

- **'System failures alone'** - everyday people making mistakes and the wider Safe System not preventing a fatality.
- **'involves illegal behaviour'** - an illegal but not reckless/extreme behaviour, such as driving without a license but otherwise compliantly, contributed to the fatality.
- **'involves reckless/extreme behaviour'**- multiple illegal behaviours or deliberate violations such as exceeding permitted alcohol levels or significant speeding.

A cluster analysis was also conducted to identify groups of crash factors that commonly co-occur, using Hierarchical Clustering on Principal Components following a multiple correspondence analysis of selected key variables. This allowed typical profiles of crashes to be developed, providing a better understanding of how system failures typically emerge together in fatal crashes.

## Findings - Literature Scan

The scan identified a wealth of literature assessing the contributing factors to road crashes, but focused primarily on previous system analysis methods and key findings. These studies consider how influences from the immediate crash circumstances through to broader organisational and regulatory settings contribute to crashes, allowing a more complete understanding. Such methods include Safe System and socio-technical approaches.

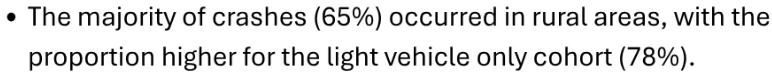
Nine studies using a Safe System framework to analyse road crashes were identified and methods from earlier analyses were gathered to inform this study's analytical approach. Previous research found that multiple system failures were evident in almost all fatal and serious crashes. Fatal crashes tended to involve the failure of more system pillars than serious injury crashes, with most occurrences involving the failure of three of more pillars. Fatal crashes were also more likely to involve reckless/extreme behaviour than less severe crashes, which more often occur due to everyday mistakes and system failures.

## Findings – Safe System Analysis

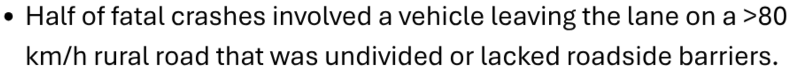
The analysis found that road fatalities almost always involved multiple system failures (99% of sample crashes), with 56% of crashes having failures implicated in all four Safe System pillars, reflecting the findings of previous Safe System analyses.

The key findings for each Safe System pillar are presented below:

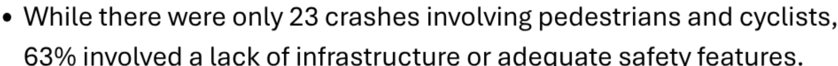
### Roads and roadsides pillar



- The majority of crashes (65%) occurred in rural areas, with the proportion higher for the light vehicle only cohort (78%).

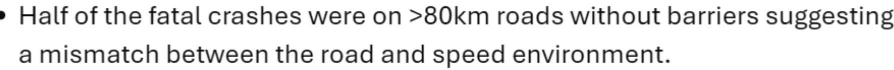


- Half of fatal crashes involved a vehicle leaving the lane on a >80 km/h rural road that was undivided or lacked roadside barriers.



- While there were only 23 crashes involving pedestrians and cyclists, 63% involved a lack of infrastructure or adequate safety features.

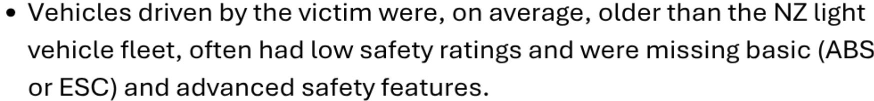
### Speed environment pillar



- Half of the fatal crashes were on >80km roads without barriers suggesting a mismatch between the road and speed environment.

- 45% of fatal crashes occurred on roads where the mean operating speed (average speed of vehicles travelling on the road) was much lower than the speed limit.

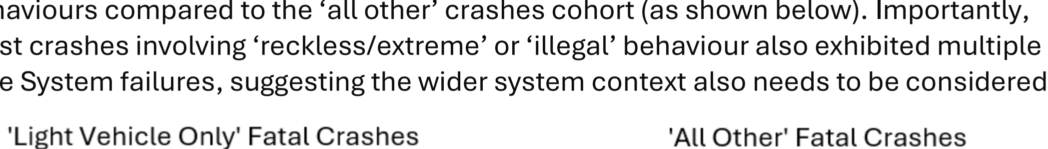
### Vehicle pillar



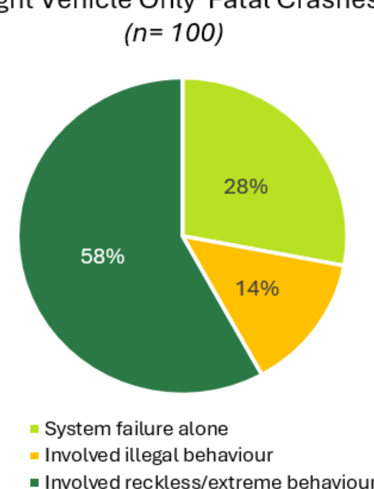
- Vehicles driven by the victim were, on average, older than the NZ light vehicle fleet, often had low safety ratings and were missing basic (ABS or ESC) and advanced safety features.
- In crashes involving multiple vehicles, the victim's vehicle was always of equal or lesser weight to the colliding vehicle.
- 70% of vehicles involved in collisions with VRUs (pedestrians, cyclists and motorcyclists) had poor VRU protection safety ratings.

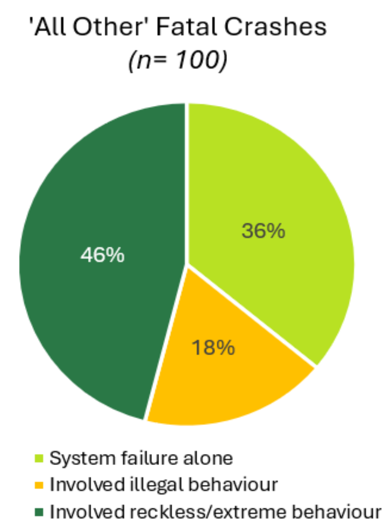
### User pillar

- 45% of the crashes involved drivers on their learner, restricted, or overseas license or driving illegally (e.g while disqualified, etc.)
- 57% of crashes involved a road user with alcohol over the legal limit, and/or illegal/ pharmaceutical drugs that affect driving.
- 47% of crashes involved speeding over 10 km/h or travelling too fast for the conditions.
- 40% of crashes involved distraction or inattention.
- In 34% of 'light vehicle only' crashes, the victim wasnt wearing a seatbelt.



The 'light vehicle only' cohort involved a greater proportion of 'reckless/extreme' behaviours compared to the 'all other' crashes cohort (as shown below). Importantly, most crashes involving 'reckless/extreme' or 'illegal' behaviour also exhibited multiple Safe System failures, suggesting the wider system context also needs to be considered.




## Findings – Crash profiles

Six fatal crash profiles were identified through a statistical cluster analysis:

**Single vehicle- run off road** (28% of crashes). Loss of control on high-speed rural roads lacking roadside barriers. Mean operating speeds (MOS) often much lower than the speed limit. Majority at night. Young developing drivers overrepresented. Speeding intoxication, and seatbelt non-use are key. Reckless behaviours in over half of cases.

**Light vehicles** (25% of crashes), mostly head-on impacts on high-speed rural roads lacking centre barriers. Young drivers and those driving with illegal licenses were overrepresented. Intoxication featured prominently alongside speeding and distraction. Strongly shaped by reckless or illegal behaviour with system failures.

**Large vs small vehicles** (15% of crashes). High mass vehicles colliding with light vehicles in head-on crashes, mostly on high-speed rural roads lacking centre barriers and less so at intersections. Mostly middle aged full licensed drivers. Frequently involved distraction/inattention and/or speed. Mostly mistakes and system failures.

**Vehicle struck pedestrian/cyclist** (11% of crashes), predominantly on urban arterial roads at intersections, or driveways. Infrastructure such as such as safe crossings and footpaths often missing. Middle aged and fully licensed drivers. Distraction/inattention (and potentially 'looked but didn't see' situations) was the dominant contributing factor. Most cases were system failures alone.

**Vehicle struck motorcycle** (11% of crashes), most often at intersections on urban and rural roads. Riders and drivers who were inexperienced and held illegal licenses. Intoxication and distraction/inattention (and potentially 'looked but didn't see' situations) were dominant factors, with speeding and extreme behaviour also often implicated. Majority involved illegal/reckless behaviours.

**Motorcycle- run off road** (10% of crashes), after losing control on rural and urban roads with operating speeds often much lower than the speed limit. Most were middle-aged, with inexperienced riders notably overrepresented. Speed and intoxication were frequent contributors. Reckless/illegal behaviour more common than system failures alone.

## Conclusions and Implications for Policy & Practice

This research found that fatal crashes occur when multiple system failures coincide, underscoring the need to address all Safe System areas to reduce fatal crashes. It reinforces that road users make mistakes which can inadvertently lead to severe consequences. However, the need for a more nuanced understanding of the road user contribution to the Safe System is also suggested. Increased illegal or reckless/extreme behaviour in fatal crashes is a possible trend, as is the changing nature of these behaviours, particularly the increased presence of drugs. Further work to more deeply understand the drivers and solutions for all road user behaviours is needed.

The work also highlighted many situations where road infrastructure or speed limit shortcomings have contributed to road users losing their lives in a range of settings. This suggests a strong road safety infrastructure programme is needed so that consistency and minimum levels of safety at a national scale can be achieved.

The vehicle contribution to fatalities is also clear from the research. Greater clarity about vehicle safety and associated education, incentives, and changes to regulatory settings are needed, focusing on vehicle age and safety features, mismatches between vehicle masses in collisions, and the aggressivity of vehicle shape in vulnerable road user collisions.

Future analyses might include serious injuries, especially if the more severe serious injuries can be identified. Wider system analyses, using socio-technical methods, are suggested to provide an understanding of the societal, policy, and organisational arrangements that set the foundations for delivering on the Safe System.

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# 1. INTRODUCTION

## 1.1. Background

Road deaths in New Zealand have reduced significantly since the mid-1980s, but despite fluctuations have remained stubbornly high at around 300-350 deaths per year for the past 10 years [1]. Beyond the tragic loss of life and potential each death represents, there is also a profound ripple effect on families, friends, and communities. These tragedies also carry significant economic costs, including lost income and opportunity, crash-related expenses, health care, and traffic delays [2,3].

The Safe System approach has framed contemporary road safety efforts in New Zealand and internationally [4]. It is deeply embedded within road safety from policy development and intervention planning to crash investigation. Human vulnerability to injury and tendency to make mistakes, along with a need to share responsibility and strengthen all parts of the system, are key Safe System principles. The four main pillars are safer roads and roadsides, safe speeds, safe road use, and safe vehicles. The Safe System pillars provide a framework for a systems analysis style approach to crash investigation. Several New Zealand and Australian studies have used crash reports to examine the involvement of each pillar in the immediate crash context [5–12].

Crash report data is provided through Police investigations and routine Traffic Crash Reports (TCR) available through the New Zealand Transport Agency Crash Analysis System (CAS). The Ministry of Transport provide road toll reporting, including trends over time and basic statistics about contributing factors (e.g., alcohol, drugs, and speed) [1]. Safe System analyses use these data sources and build on them with other data, such as road and vehicle design features, to provide a deeper understanding of the nature and typology of crashes, including how factors come together, leading to road crashes.

A Safe System analysis using New Zealand data was undertaken by Mackie Research in 2017 [6]. The work focused on building a better understanding of Safe System contributors to deaths and serious injuries using light vehicle only crash data from 2015/16. A key finding was that the proportion of fatal and serious crashes which involved:

- **'System Failures'** - everyday people making mistakes and the wider Safe System not preventing a death or serious injury.
- **'Reckless Behaviour'**- deliberate violations such as exceeding the permitted alcohol levels or significant speeding.

Since 2017, there have been a range of societal and policy developments in New Zealand. It is timely to revisit Safe System crash research, drawing on the methodologies developed for earlier research with further refinement as needed, particularly where changes have occurred in the information collected and held in CAS (e.g. the presence of drugs in road users involved in crashes is now reported).

This study provides an analysis using recent fatal crash data from the 2024 calendar year, which at the time of the project was the most complete dataset sufficiently clear of post-Covid-19 pandemic effects. The analysis included two cohorts of crashes, 'light vehicle only' and 'all other' crashes, which collectively represent 80% of all fatal crashes in 2024. Together, this will allow comparison with the findings of Mackie et al. (2017) and enable an assessment of changes overtime. It will also provide a broader understanding of the contributing factors to fatal crashes involving a representative range of road users.

*Why fatal crashes?*

We acknowledge that the Safe System approach focusses on both deaths and serious injuries (DSIs). However, serious injury data in New Zealand covers a large range of situations and injuries considered 'serious' [6]. In New Zealand, there isn't a category of 'very serious' injuries which would be a more homogenous group to analyse.

There is a case for research focused specifically on fatalities because they represent the greatest human cost, reflected by the $14.9m social cost of a road fatality as determined by the Ministry of Transport [2]. Furthermore, fatal crashes also tend to occur when the system has failed completely, meaning that with better understanding, there are multiple potential intervention points within the system to prevent them.

It is also worth noting that fatal crashes are more prevalent in rural, high-speed road environments, frequently involving one or more light vehicles. In contrast, there are proportionately more serious injury crashes on urban roads with lower speeds which involve a wider range of road users [1]. This bias was partly offset by the inclusion of a sub-cohort of crashes involving road users other than only light vehicles (see Section 2.2). This provided greater coverage of urban fatal crashes, which are more likely to include a wider mix of road users.

Given the resources available for this intensive analysis, a focus on fatal crashes was chosen to better understand the most severe crashes that happen, within a relatively homogeneous dataset. Based on evidence, these findings will assist policymakers and others communicate the areas that require focus if we are to drive down road deaths in New Zealand. The findings could also be used for deeper dives into areas of concern. We suggest that further research carries out similar analyses for serious injuries, ideally 'very serious' injuries, thus capturing the full range of crashes that are of primary interest under a Safe System approach.

## 1.2. Objectives

The purpose of this work is to examine the Safe System determinants of fatal crashes in New Zealand occurring in the 2024 calendar year. Specifically, this project addresses the following research questions:

1. What are the Safe System determinants of fatal road crashes in New Zealand, as defined by previous research?
2. What proportion of crashes result from everyday mistakes and 'system failures', compared with crashes where illegal or reckless/extreme behaviour was involved?
3. What are the implications of the findings for policy and practice?

# 2. RESEARCH APPROACH

This research was conducted in two phases. The first phase involved a literature scan of research focused on previous system analyses of fatal crashes. The second phase involved an analysis of fatal crash cases and relevant datasets to better understand the factors contributing to crashes. A cluster analysis was then conducted to identify contributing factors that commonly co-occur.

## 2.1. Literature scan

A brief, focused literature scan identifying system analyses of fatal crashes was completed. The purpose of the scan was twofold:

1. To test and refine the project methodology by reviewing methodological approaches used in similar studies.
2. To gather findings from similar studies to enable comparisons with the data and analyses arising from this work.

The scan did not aim to cover wider literature on contributing factors to fatal crashes.

Although this project was focused on fatal crashes, system analyses of serious injury crashes were also gathered during the scan. This was because there was limited published research focused on fatal crashes alone. Previous studies have shown serious injury crashes differ from fatal crashes (with fatal crashes often involving more complexity and contributing factors). However, there are sufficient commonalities between serious and fatal crashes to justify their inclusion, particularly in terms of method development.

A summary of the search strategy, and specific search terms is provided in Appendix A. The findings of the literature review are summarised in Section 3.

## 2.2. Fatal crash dataset selection

Crash data was obtained from the NZTA CAS database. A search for all fatal crashes occurring in the 2024 calendar year was completed. This provided an output containing 250 crash reports. From this output, two cohorts of 100 crashes each were selected to make up the total of 200 cases analysed. The cohorts were:

- **Cohort 1- Light vehicle only crashes:** fatal crashes involving only light vehicles (car, van, or utility, or SUV/4x4), where the driver or passengers were killed. This includes single vehicle crashes, and crashes involving multiple light vehicles.
- **Cohort 2- All other crashes:** all other fatal crashes excluding rare crash types.[1] This included crashes involving trucks/heavy vehicles, buses, motorcycles/ mopeds, cyclists, and pedestrians, but also often light vehicles.

[1] Rare crash types included: bus or cyclist only crashes, cyclist and pedestrian crashes, crashes involving trains, and crashes involving other vehicles (e.g. tractors and quadbikes).

The purpose of Cohort 1 was to enable comparison to the results of the Mackie et al. (2017) [6]. The 100 fatal crashes analysed in Mackie et al. (2017) were compared to Cohort 1 to determine changes in the contributing factors since the initial study. Cohort 2 was selected to enable analysis of a wider range of crash typologies giving a more complete view of fatal crashes in New Zealand. By including crashes involving a wider range of road users, we can assess the full range of contributing factors resulting in road fatalities.

Figure 1 summarises the approach used to sample crashes for inclusion into each cohort.

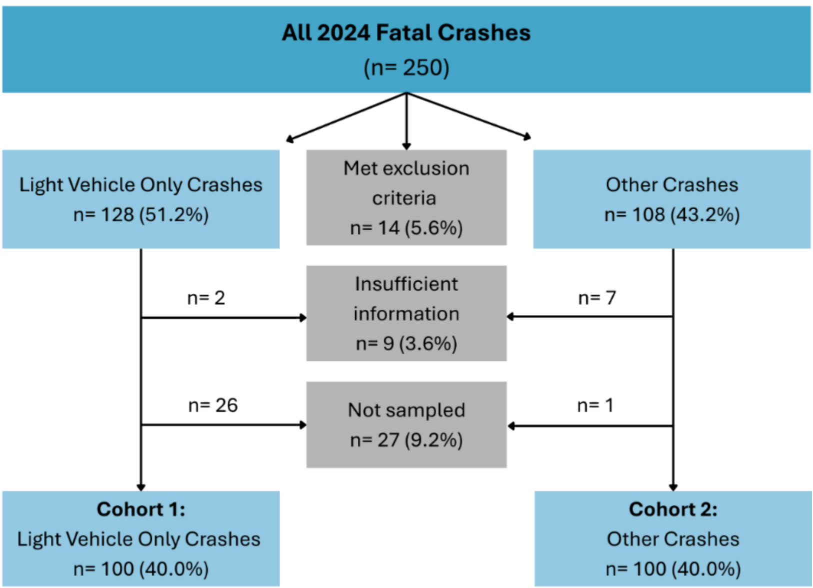



*Figure 1: Flowchart summarising the crash selection process.*

Firstly, crashes were assessed to determine whether they met the criteria for inclusion in either of the cohorts as defined earlier. In order to maintain a relatively homogenous dataset, crashes were also assessed against exclusion criteria and removed if they met one of the following criteria:

- Rare crash types: bus- or cyclist-only crashes, cyclist-pedestrian crashes, and crashes involving trains or other vehicle types (e.g. tractors and quadbikes).
- Crashes where the driver of the colliding vehicle fled the scene and the person/vehicle was unable to be identified.
- Crashes that occurred in car parks or other off-road locations.

From the eligible cases for each cohort, 100 crashes were randomly sampled by allocating each crash a random number and selecting the first 100 crashes. Each selected crash was reviewed to ensure that sufficient information was available to code the contributing factors. Where there was insufficient information in the TCR to perform the analysis (e.g. the case was still under investigation and details were missing), the crash was excluded and the next crash was included in the sample (i.e. if any of crashes 1-100 were excluded, crash 101 was selected).

Overall, the cohort represents 80% of all fatal crashes in the 2024 calendar year. The light vehicle only and all other crashes cohorts represent 79% and 99% of all eligible cases respectively. This means that the overall sample is slightly under representative of light vehicle only crashes and over representative of the other crash types.

## 2.3. Safe System analysis procedure

*Coding framework*

The 200 fatal crash cases were coded using a Safe System analysis coding framework to identify the factors contributing to the crash. The coding framework used in this study is a modified version of the framework developed for the Serious Injury Crashes study by Mackie et al., 2017 which focused on light vehicle crashes. Several crash factors were added or adjusted to reflect changes in data availability (e.g. the addition of drug reporting in TCRs, and the removal of Safe and Appropriate Speed Limits from Mega Maps 2024 edition), vehicle technology, and the wider range of crash types, including other vehicles and vulnerable road users (VRUs)[2] analysed in this project. Frameworks from other previous Safe System analyses were drawn upon to inform this process [5,7–9].

A key distinction between the frameworks used in Mackie et al. (2017) and this project is the addition of the 'illegal behaviour' category in line with the 'illegal system failure' category in the work by the Centre for Automotive Safety Research (CASR), South Australia [8,9]. This recognised the continuum of crash circumstances between 'system failures' and 'reckless/extreme behaviour'. The definition of these categories is below:

- **'System failures alone'** - everyday people making mistakes and the wider Safe System not preventing a fatality.
- **'Illegal behaviour'** - an illegal but not reckless/extreme behaviour, such as driving without a license but otherwise compliantly, contributed to the fatality.
- **'Reckless/extreme behaviour'**- multiple illegal behaviours or deliberate violations such as exceeding permitted alcohol levels or significant speeding.

While the definitions used in the present study are similar to the work by CASR, methodological differences remain with Wundersitz & Raftery (2025) setting higher thresholds for reckless/extreme behaviour for some contributors. For example, vehicles had to be travelling at more than 50% over the speed limit, while the present study used a blanket value of >=20 km/h over the posted speed limit. Also, Wundersitz & Raftery didn't include pharmaceutical drugs which affect driving in their framework.

It's also worth noting that, in the present study, the presence of drugs - illicit or pharmaceuticals that affect driving (illegal behaviour trigger) and the presence of alcohol over the legal limit (reckless/extreme behaviour trigger) were treated differently. This is because testing blood/breath alcohol concentration provides a known intoxication, whereas drug testing only indicates a drug's presence, with the level of intoxication unknown. For example, a positive test could result from trace levels of a drug taken 1-2 days ago which is no longer causing impairment. However, if other behaviours suggesting intoxication were also present (e.g. speeding) alongside drugs, the crash was coded as involving reckless behaviour. Wundersitz & Raftery, 2025 took the same approach.

Figure 2 summarises the Safe System analysis framework, including the crash factors in each Safe System Pillar (speed environment, vehicle, roads and roadsides, and user) and those that indicate 'illegal' or 'reckless/extreme behaviour' and other contextual factors.

---

[2] Vulnerable road users will hereon be used to refer to pedestrians, cyclists, motorcyclists/ mopeds, and other wheeled users.

# Analysis Framework for All Crashes

## Crash Information

**TCR Coding**

- Crash ID
- Time, date, day
- Region
- Road users involved
- Number of other parties (vehicles, road users outside vehicle) involved
- Crash description and comments
- Crash factors
- Crash road, feature
- Weather and lighting conditions
- Number and severity of injuries
- Person/people fatally injured
- Crash movement
- Crash impact type
- Post impact factors contribute to fatality

## Speed Environment Pillar

**TCR Coding**

- Speed limit
- Advisory speed
- Extraordinary speed factors (*team to review*)

**Other data coding-** Mega Maps

- Mean operating speed- 2024

**Speed Environment triggers (one or more)**

- Mean operating speed 10km/h < speed limit
- Mean operating speed 5km/h > speed limit
- *If relevant to crash:*
  - Crash occurred on >80km/hr rural road without centre median or roadside barriers
  - Crash involves pedestrian or cyclist on local road, town centre, outside school where speed limit is >30km/hr

## Vehicle Pillar

### Victim's vehicle (*in which the fatality occurred*)

**TCR Coding**

- Vehicle type
- Vehicle make/model
- Vehicle year/age
- Did it roll?
- WoF/CoF
- Defects/extraordinary vehicle factors (*team to review*)

**Other data coding**

*How safe is your car*

- Driver protection star rating (USCR/ ANCAP / ENCAP)
- Airbags equipped?
- Basic crash avoidance features equipped? (ESC, ABS)
- Advanced crash avoidance features relevant to the crash type equipped?

### Colliding vehicle (*if present*)

**TCR Coding**

- Vehicle type
- Vehicle make/model
- Vehicle year/age
- WoF/CoF
- Defects/extraordinary vehicle factors (*team to review*)

**Other data coding**

*How safe is your car*

If crash involves a VRU:

- VRU protection star rating (USCR/ ANCAP / ENCAP)

**Vehicle Pillar triggers (one or more)**

- Victim's vehicle >= 14 years old
- Victim's vehicle- no WoF/CoF
- Victim's vehicle- safety star rating 1-3
- Victim's vehicle- missing basic crash avoidance features
- Victim's vehicle- relevant stated vehicle defects
- *If relevant to crash:*
  - Victim's vehicle is missing relevant airbags
  - Victim's vehicle is missing advanced crash avoidance features that could have prevented the crash
  - Victims' vehicle has a much lower mass than the colliding vehicle
  - Vehicle that struck VRU is a truck, bus, SUV, ute, van
  - Colliding vehicle has VRU safety star rating 1-3

## Roads and Roadsides Pillar

**TCR Coding**

- Crash location
- Junction type
- Traffic control
- Road surface type and conditions
- Other notable factors mentioned (*team to review*)
- Roadside object struck
  - Yes/No
  - What was stuck
- *If relevant:*
  - Street lighting conditions

**Other data coding**

*Mega Maps*

- Infrastructure risk rating (IRR)
- Road stereotype
- Road alignment
- Shoulder width
- Road function- ONRC
- Land use
- Annual Average Daily Traffic (AADT)

*Google Street View*

If relevant to crash:

- Roadside barriers
- Centre barriers
- Fog/edge lines
- Sealed road shoulder
- Audio tactile line markings
- Wide centrelines/median
- Footpath
- Crossing facilities
- Cycling facilities

**Road & Roadsides Pillar triggers (one or more)**

- Struck non-frangible roadside object
- IRR- medium high or high
- *If relevant to the crash*:
  - Undivided >80km/hr road
  - No street lighting
  - Obstructed view /intersection lacking continuity cues
  - Surface condition factors
  - No crossing facilities or lacking safety features
  - No footpath
  - No cycling infrastructure
- Other notable road and roadside factors

## User Pillar & Illegal/Reckless Behaviour

**TCR Coding- each primary road user involved in crash**

- Age
- Gender
- License type (if relevant)
- Breach of license conditions if learner or restricted licence (if relevant)

**TCR Coding- present in crash**

- Alcohol presence and reading
- Drug presence and listed drugs
- Clearly intoxicated
- Evidence of fatigue
- Evidence of distraction
- Emotional state and description
- Medical condition contributing and description

**Vehicle/motorbike/moped factors**

*If relevant:*

- Failed to maintain a safe following distance
- Unsafe overtaking
- Ran red light/failed to give way/ stop at a stop sign
- Loss of control
- Crossed the centreline

*If relevant:*

- Restraint worn
- Vehicle speed
- Too fast for the conditions?
- Other notable behaviours *(team to review)*

**Vulnerable road user factors**

*If relevant:*

- Lane splitting
- Dark clothing at night
- Unpredictable change of direction
- Insufficient checks of surroundings
- Lying on road

*If relevant:*

- Helmet worn
- Protection gear worn
- Crash on VRU priority facility
- Other notable behaviours *(team to review)*

**User Pillar triggers (one or more)**

- Driver age <=16, >=75
- VRU age <=12, >=75
- Alcohol test over the legal limit
- Illicit or pharmaceutical drug that affects driving present
- Clearly intoxicated
- License type = learner, restricted, forbidden, disqualified, no license, expired, wrong type, or overseas
- Breach of licence conditions (learner/ restricted)
- Restraint not worn (victim)
- Fatigue evident
- Distraction evident
- Poor emotional state
- Medical event directly contributing to crash
- Other notable behaviours (*team to review*)
- Crossed centreline
- Loss of control
- Left road to left
- Ran red light/failed to give way/ stop at a stop sign
- Unsafe overtaking
- Failed to maintain safe following distance
- Vehicle speed >=10 km/h over posted speed limit or mean operating speed
- Vehicle speed faster than speed advisory
- Too fast for the conditions
- Hit pedestrian/cyclist on priority facility
- Lane splitting
- Dark clothing at night
- Unpredictable change of direction
- Insufficient checks of surroundings
- Lying on road
- No helmet worn- motorcyclist
- No protection gear worn- motorcyclist

**Illegal behaviour triggers (one of the below):**

- Illicit or pharmaceutical drug that affects driving present
- Disqualified driver, wrong license type, expired license
- Breach of license conditions
- >=10 km/hr over speed limit
- Restraint not worn (victim)

**Reckless/extreme behaviour triggers (one or more)**

- Any two or more of the illegal behaviour triggers
- Alcohol test over legal limit
- Clearly intoxicated
- No license or forbidden driver
- >=20 km/hr over speed limit
- Poor emotional state
- Attempted suicide or murder
- No helmet worn (motorcyclist)
- Lying on road (pedestrian)
- Running onto road heedlessly of traffic/ deliberately (pedestrian)
- Other extreme behaviours (*team to review*)

Figure 2: Safe System crash analysis coding framework.

### *Data sources*

Figure 2 also indicates the data source used for each crash factor. Details about each information sources are provided below:

- **TCRs from CAS**: provides routinely collected crash details related to most aspects of the crash circumstances and contextual information. These reports are written by the responding Police Officer to a crash. However, where fatalities occur, and sometimes where serious injuries occur, a Serious Crash Unit (SCU) investigation is carried out, and a more detailed report completed. High level findings of the SCU are added into the TCR in CAS following completion of the investigation. SCU reports provide a more detailed summary of the crash circumstances and contributing/ contextual factors, however due to privacy restrictions it is very difficult to acquire these for research purposes, hence only TCRs were used for this project. Earlier investigations have found that, although there are many limitations of TCRs, they are generally reliable for understanding the basic contributing factors to crashes.
- **Safer Journeys Risk Assessment tool 2024 edition (Mega Maps):** A geospatial platform which provides information about speed and road characteristics, and infrastructure risk for all roads in New Zealand. MegaMaps is routinely used by Road Controlling Authorities to review and set speed limits.
- **Howsafeisyourcar.com.au:** A website hosted by the Australian Transport Accident Commission and Victoria State Government which provides detailed information about light vehicle safety ratings and features. This doesn't extend to other vehicles such as motorcycles, mopeds, trucks, or buses. Previous projects have used Rightcar, NZTA's vehicle safety and efficiency rating tool. However, information was regularly missing, particularly for older vehicles, so the Australian platform was used instead.
- **Google Street View:** Used to visually assess whether the road and roadside at the crash location had relevant safety features (e.g. roadside barriers, edge lines, or crossing facilities). The image taken closest to the crash date was used, although there is a chance that very recent road improvements are not shown in Street View.

### *Coding process*

The coding process involved reviewing the information available for each crash case and entering data for each relevant crash factor in the Safe System crash analysis framework (Figure 2) into a coding spreadsheet. The coding spreadsheet was designed to eliminate coding error by including drop-down lists rather than allowing for open-ended responses. The values entered for the crash factors in each pillar then determined whether that pillar was 'triggered' in each crash (i.e. implicated in the occurrence/severity of the crash).

Three members of the research team were trained to code crashes using an extensive protocol document that was designed to ensure consistency between coders. The protocol included a process for coding each crash, the pillar triggers, and instructions for coding crash factors where judgement was required to determine whether that factor was implicated (e.g. evidence of fatigue or distraction). The protocol was discussed and refined through initial training meetings and inter-rater reliability exercises.

Throughout the coding process, a team member was allocated as the ‘master coder’ who reviewed a selection of each coder’s work to check for discrepancies from the agreed protocol, ensuring a consistent coding approach. Regular meetings were also held to aid in consistency and to provide a forum for discussing difficult cases as they arose.

Finally, once coding was complete for the whole dataset, difficult cases and complex variables such as ‘evidence of distraction/inattention’ were reviewed by the ‘master coder’. Where further input was required, cases were discussed with the wider project team, with the coding adjusted as necessary.

*Inter-rater reliability*

Prior to beginning the coding process, a pilot analysis including two inter-rater exercises were completed to aid with coder training and ensure consistent treatment of crash cases. In the first exercise, five crash cases were coded independently by three members of the research team, and in the second exercise, a further five crash cases were coded.

Inter-rater reliability testing as described by Hirsch et al. (2018) was completed for the five cases analysed in the second exercise. All coding discrepancies were converted into kappa scores to assess the level of consensus in how coding of crash cases was assigned to different categories. Kappa scores measure the rating reliability between two or more raters for qualitative variables, corrected for the likelihood that raters may agree by chance. Scores can range from -1.0 (perfect disagreement) to 1.0 (perfect agreement), with a score of 0.0 indicating the raters agreed at a level equal to chance. A score of 0.70 or above is generally viewed as adequate. A free-marginal kappa score was used in this study as there were no restrictions on how many cases could be assigned to each category (Siegel & Castellan, 1988).

For each crash, a total of 133 qualitative variables with predefined categories were coded (descriptions and numerical values were excluded). Of these, 105 variables had perfect agreement, scoring 1.0. For the remaining 28 variables, scores ranged from -0.33 to 0.86. The overall average for all variables was therefore 0.86. Categories with poor interrater score were reviewed by the project team and more instruction provided to coders to ensure consistency going forward.

Following the interrater exercises, any discrepancies in coding (including descriptions and numerical values) were reviewed, discussed, and a consistent approach was agreed and outlined in the coding protocol.

## 2.4. Descriptive analysis

Once coding was complete, a descriptive analysis was carried out for each variable included in the framework. Results were analysed and summarised for the whole sample (n= 200), and the ‘light vehicle only’ crashes (n=100) and ‘all other’ crashes (n=100) cohorts. Total number of crashes was used as the denominator to enable comparison across crashes regardless of the number of crash parties or road users involved or the number of people injured in the crash.

## 2.5. Statistical cluster analysis

A statistical cluster analysis was conducted to identify and define ‘clusters’ of crash factors (variables) that tended to occur together using Hierarchical Clustering on Principal Components following a multiple correspondence analysis of selected key variables. The specific approach mirrored the method used in the previous driving for work study [7].

*Variables of interest*

The project team met to prioritise approximately 20 variables for inclusion in the cluster analysis in order to provide a coverage of the contributing factors, while not weakening the model by including too many variables. The following variables were considered most relevant in analysing and characterising the profiles of fatal crashes:

- Crash type
- Crash impact type
- Victims’ vehicle type
- Colliding vehicle type
- Crash location type
- Lighting conditions
- Weather conditions
- Ratio of MOS to the posted speed limit at the crash location
- Overall vehicle safety rating for the victims’ vehicle
- Unequal vehicle mass in collision
- Land use at crash location
- License type
- Road user age (categories- 25 years or younger, 26 to 74 years old, and 75 years or older)
- Speed implicated (binary- yes/no category combining travelling over speed limit/ MOS/ advisory speed, and too fast for the conditions)
- Evidence of distraction or inattention (binary- yes/no category combining evidence of fatigue, distraction and insufficient checks)
- Intoxication present (binary- yes/no category combining alcohol over the legal limit and the presence of drugs)
- Restraint worn

*Multiple correspondence analysis*

Multiple correspondence analysis (MCA) was performed using software R (version 4.5.2) and statistical packages ‘FactoMineR’ and ‘Factoextra’. Given most of the variables were categorical, and there is no intrinsic ordering to the categories, an MCA was conducted.

MCA turns categorical data into numerical dimensions by converting each category into a binary indicator, then looking at how often those categories occur together. It applies a principal component analysis-like process to find axes that best summarize these patterns, giving each category within a variable a numerical position that reflects its similarities and differences, in relation to other variables included in the MCA. In the transformed data space, two axes are selected to explains the first and second most variance in the multidimensional data cloud.

### *Cluster analysis*

To identify crashes with similar attributes, cluster analysis was performed on the MCA results obtained. To achieve the best clustering outcomes, the Hierarchical Clustering on Principle Components (HCPC) approach was employed. This approach conducts a clustering algorithm based on the MCA results and allows for consolidation between hierarchical clustering and partitioning clustering. Hierarchical clustering is based on Ward's criterion to minimise within cluster variance, whereas partitioning clustering minimises the total within sample variance.

The clusters identified using the HCPC approach were validated using non-hierarchical clustering with the k-means algorithm to split the data into groups. This was done to confirm that the clusters developed were valid and robust.

# 3. FINDINGS - LITERATURE SCAN

This section presents the findings from the literature scan on system analyses of fatal crashes. To set the context, it begins with a brief description of the range of approaches that can be taken to analysing contributing factors in road crashes. It then focusses on the methodological approaches and key findings from system-level analyses.

## 3.1. Analysing contributing factors to road crashes

There is a large body of research examining factors contributing to road crashes. These range from basic analyses quantifying the contribution of individual factors (often used for problem definition) to system approaches examining how multiple factors interact and come together to contribute to road crashes. System analyses consider influences across the entire road safety framework, from broad regulatory settings through to immediate environmental conditions. Figure 1 shows the different approaches, with increasing complexity of analysis, from left to right.

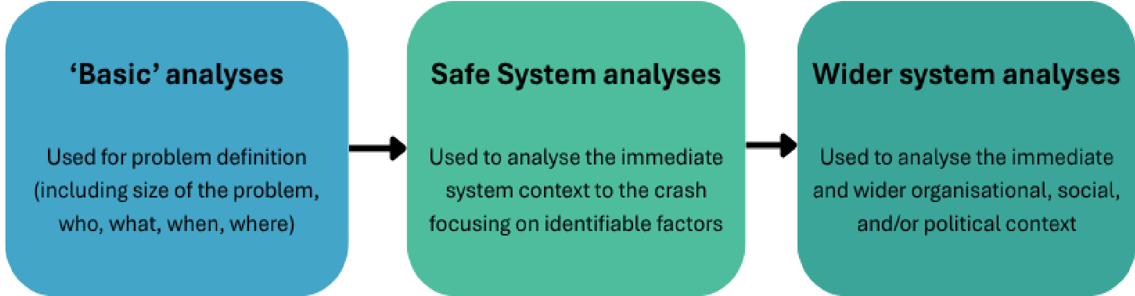



*Figure 3: Approaches for analysing contributing factors to road crashes, increasing in complexity from left to right. Adapted from Thorne et al. (2022) [13].*

Most literature published on contributing factors to crashes involves 'basic' analyses. These are typically studies of the influence of factors involved in crashes for different road users (e.g. cyclists, pedestrians, young drivers, etc.) [14–18], or of common contributing factors (e.g. use of restraints, the influence of alcohol, etc.) [19,20]. Since 'basic' analyses are not the focus of this review, the findings from these studies are not discussed.

In recent years, system analyses of vehicle crashes have become more common. This reflects the uptake of the Safe System approach, described in detail in the following section. Focusing on system components, rather than only individual factors, allows for a more complete understanding of how contributing environmental factors come together in road crashes. System analyses range from immediate system context and analyses identifiable crash factors, through to broader system analyses (e.g. using a socio-technical approach) which examine the wider context that contribute to incidents, such as the regulatory environment.

The following sections provide more detail on different methods used to undertake systems analyses and summarise findings from previous Safe System analyses of road crashes in New Zealand.

## 3.2. Methodological approaches to system analyses

*Safe System analyses*

The Safe System approach originated in Sweden in the late 1990s as part of its Vision Zero strategy (1997). The approach is built on the idea that no loss of life on the roads is acceptable, and that the transport system should be designed to account for human mistakes and vulnerabilities.

It has been taken up widely around the world and a Safe System framework was formally introduced to New Zealand in 2010, when the Government launched the Safer Journeys 2010–2020 road safety strategy. Figure 4 illustrates the main areas of New Zealand's Safe System model.

*Figure 4: Safe System approach to road safety (Ministry of Transport, 2010). [4]*

The Safe System has framed contemporary road safety efforts in New Zealand. It is embedded broadly from policy development and intervention planning to crash investigation. The four main pillars are safer roads and roadsides, safe speeds, safe road use, and safe vehicles.

The framework has also been applied to systems analyses of crashes, using the four Safe System pillars to examine the factors that contribute to crash occurrence. The Safe System analysis approach tends to focus on the immediate crash context and is usually based around examination of crash reports and other data. Often, the frequency with which different factors contribute to a sample of crashes is considered (e.g., speed, alcohol, or road design). The outputs of these analyses provide an understanding of the nature and typology of crashes, including how contributing environmental factors come together leading to crashes. In some cases, they have been used to inform more detailed socio-technical analyses.

Examples of this research include Wundersitz et al. (2014) and Wundersitz & Raftery (2025) in South Australia [8,9], McTiernan et al. (2019) in the Australian Capital Territory (ACT) [10], and Mackie et al. (2017), Thorne et al. (2020), Hirsch et al. (2021), and Raja et al. (2023) in New Zealand [5–7,11].

**Summary of Safe System studies- samples/methods**

Of the previous Safe System crash analyses identified in this review, all but one included both fatal and serious injury crashes in their sample, with one study only including fatal crashes. Four projects were conducted in New Zealand, and three were based in Australia, namely South Australia (2), and ACT (1). The three Australian papers included all road types in their sample, while the New Zealand studies focused on road user groups, specifically light vehicle occupants (1), pedestrians (2), and those driving for work (1).

All seven studies used various combinations of TCRs, crash investigation/coroners' reports and a Safe System framework to analyse whether failure of the four Safe System pillars were implicated in a crash. Four out of the seven projects also considered reckless/extreme behaviour independently to the Safe System user pillar [6–9]. The definition of reckless/extreme behaviour was similar between papers and included behaviours such as the drivers' blood alcohol content above legal limits, positive for illicit drugs, travelling significantly over the speed limit, and other deliberate reckless behaviours (e.g. dangerous overtaking or pedestrians heedlessly running into traffic). Other circumstances such as driving while unlicensed or disqualified, or not wearing a seat belt, were also taken into consideration. One difference is that cases of attempted suicide/murder or medical events directly contributing to a crash were excluded from the South Australian studies [8,9], but included in the New Zealand studies [6,7].

The South Australian studies used coroners' reports for fatal crashes and in-depth crash investigation reports provided by CASR [8,9]. These reports are highly detailed, and the researchers did not refer to any further datasets. The ACT study only used TCRs and related crash data [10]. In comparison, the four New Zealand studies used TCRs for crashes of all severity, as they did not have access to SCU reports [5–7,11]. However, further supplementary datasets were used to provide information for some of the Safe System pillars, including vehicle safety features and ratings, details about speed and road risk, roadside conditions, and in the pedestrian studies, Vehicle Aggressivity ratings.

### *Wider system analyses*

Systems theory and thinking is a common approach used broadly in safety science disciplines, including road safety. It provides theories and methods to support incident analysis and prevention activities. Contemporary models are underpinned by the notion that incidents arise from interactions between multiple components across entire systems.

Considering the influence of the entire system on safety promotes shared responsibility for incidents across all actors, including government. This provides a foundation for a collaborative approach to risk management.

### Socio-technical systems analysis

One commonly used systems analysis method is the socio- technical systems approach. Rasmussen's risk management framework (Figure 5) combined with an associated Accimap technique to identify contributing factors to incidents in complex systems [21] is a common application of socio-technical systems principles. The Accimap (and contributing ActorMap) graphically represents how system factors (including conditions, decisions, and actions of various actors within the system) interact with one another to create the incident under analysis.

This approach goes beyond Safe System approaches by taking a whole of system view from the proximal through to upstream factors. It aims to provide pathways for prevention efforts beyond the immediate context because, in many cases, incidents can only be prevented by action further upstream.

Examples of a socio-technical approach to analysing road crashes include:

- Newnam & Goode, 2015. Do not blame the driver: A systems analysis of the causes of road freight crashes [22].
- Salmon et al., 2019. Bad behaviour or societal failure? Perceptions of the factors contributing to drivers' engagement in the fatal five driving behaviours [23].
- Mackie et al., 2017. Towards a Safe System for cycling: Development and application of a cycling safety system model preparing New Zealanders for utility cycling [24].
- Raja et al., 2023. Driving for work crashes: A systems analysis [7].[3]

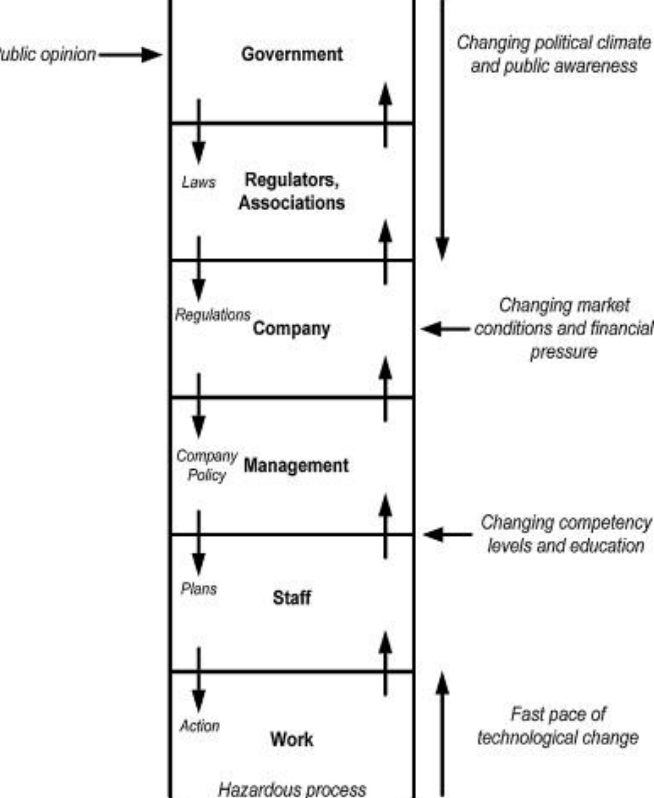



*Figure 5: Rasmussen's risk management framework (Rasmussen, 1997).*

### Haddon Matrix

Another well established and commonly used approach to injury prevention in road safety is the Haddon matrix (Figure 6). The matrix combines Safe System and sociotechnical approaches by considering both proximal factors (e.g., person and vehicle) and broader social and environmental factors at different time points (before, during, and after the crash). This provides a broad perspective on the crash context.

[3] This paper used both a Safe System and Socio-technical approach to analyse driving for work crashes in New Zealand.

| Phases | Factors | | | |
|---|---|---|---|---|
| | Person | Vehicle | Physical environment | Social environment |
| Pre-crash | | | | |
| During crash | | | | |
| Post-crash | | | | |

*Figure 6: A typical version of the Haddon Matrix, as applied to road safety [24].*

An example of Haddon matrix methodology use is provided by the multi-year Enhanced Crash Investigation Study conducted by Monash University in Victoria, Australia [25]. The study gathered data related to 400 incidents where seriously injured drivers were admitted to The Alfred and Royal Melbourne hospitals between mid-2014 to mid-2016. Analyses included comprehensive scene and vehicle investigations, computer-based crash reconstruction, and interviews with drivers. The Haddon matrix was used to identify contributing factors and assess their impact on crash occurrence and injury severity.

**Human Factors Analysis and Classification System (HFACS)**

HFACS is based on Reason's (1990) Swiss cheese model and has been applied in many safety-related disciplines, including road safety. Reason's model and the HFACS framework identify four system layers: unsafe acts, pre-conditions for unsafe acts, unsafe supervision, and organisational influences (Figure 7). The model posits that for an incident to happen, failings at multiple layers must occur at the same time, otherwise various system factors act as a 'backstop' preventing the incident.

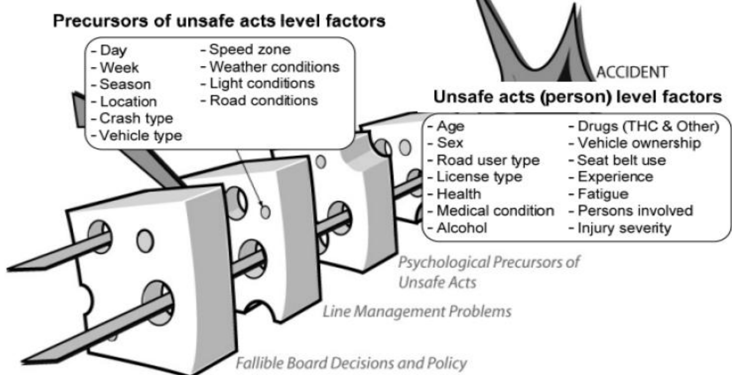



*Figure 7: HFACS and fatal road crash data mapped onto Reason's Swiss cheese model. Adapted from Salmon & Lenne (2009).*

The HFACS model was recently used in a large study of road traffic accidents covering 28 provinces in China [26]. Data was gathered from a representative sample of 396 crashes using traffic crash reports and other government data sources. Analysis involved coding incident reports using a framework developed based on the HFACS model combined with a contributory factor interactions model. The frequency of contributory factors and interactions between factors were analysed to understand the cohort of crashes.

Other system focused incident analysis models are also commonly used in road safety but are not discussed further in this brief review.

## 3.3. Findings from Safe System crash analyses

This section provides key findings from previous Safe System analyses, before identifying gaps in the current research. Through the literature scan, nine studies using a Safe System framework to analyse road crashes were identified. Table 1 provides a summary of the objectives, methods, and findings of seven of these studies. Two smaller projects analysing the Christmas/New Year holiday road toll in New Zealand were omitted because they were smaller in scope and were not comparable to the other larger studies [27,28].

The findings of previous analyses are remarkably similar despite the differences in samples and road user types. All analyses found that multiple system failures were evident in almost all fatal and serious crash events [5–9].[4] Fatal crashes tended to involve failure of more system pillars than serious injury crashes, with most occurrences involving failure of three of more pillars.

Reckless/extreme behaviour was more often implicated in fatal crashes (20-47%) than serious injury crashes (6-30%) [5–9]. It was also less frequently implicated in driving for work crashes than general crashes [7]. Crashes involving extreme/reckless behaviours often involved multiple non-compliant behaviours (e.g. alcohol in combination with drug use or no seat belt worn). Interestingly, in the repeated South Australian studies, significantly fewer crashes were attributed to extreme behaviours in the 2014-15 period than in 2008-09 (30% vs 46%), with less alcohol involvement in the latest study period. This was attributed to lower levels of alcohol consumption overtime in South Australia [8].

### *New Zealand research gaps*

While several New Zealand-focused Safe System analyses have been conducted, they use crash data from the years 2011-2020 which, at the time of writing, is six years or more old. There have been several major road safety policy and societal changes resulting from the Covid-19 pandemic, particularly the change in travel behaviours to more working from home and anecdotal evidence of more extreme driving behaviour. Also, since the previous work, the presence of illegal drugs in drivers involved in crashes has begun to be included in TCRs. There is a need for updated research that reflects these major changes.

In addition, the previous New Zealand studies have focused on single user group samples (light vehicle users, pedestrians, and those driving for work). There is a need for an up-to-date study that includes a wider range of road user types to reflect the full range of fatal crashes that occur on New Zealand roads.

While more comprehensive systems analyses provide a detailed whole of system view of road crash incidents, they require more complex data which is resource intensive to gather and analyse. Also, as mentioned previously, the availability of SCU and other detailed data is an issue in New Zealand [5,7]. A Safe System analysis approach, however, can utilise data from TCRs, such as that available in CAS, and provide insights to inform prevention efforts and policy direction, and provide a base for more detailed socio-technical systems analyses, hence the direction for this project.

[4] McTiernan et al., 2019 was a conference paper which wasn't reported in a similar form as the other six analyses. It was difficult to determine whether the results were comparable with the information available.

*Table 1: Summary of previous Safe System road crash analyses.*

| Citation | Purpose/Scope | Sample | Data | Results |
|---|---|---|---|---|
| Mackie et al., 2017. [6] | To identify differences between fatal and serious injury light vehicle crashes in New Zealand, and the proportion resulting from system factors/reckless behaviours. | 200 serious injury crashes and 100 fatal crashes involving light vehicles in 2015/16. | Traffic crash reports, and information about vehicle safety ratings, speed, and road risk. | Multiple system failures were evident in the majority of fatal (99%) and serious injury crashes (93%), but fatal crashes were more likely to involve all four pillars of the Safe System. Reckless behaviour was a contributing factor in more fatal crashes (47%) than serious injury crashes (30%). |
| Wundersitz et al., 2014. [9] | To examine the relative contribution of system failures and extreme behaviour in South Australian crashes, and differences between fatal urban/rural injury crashes. | 189 fatal crashes, 272 urban and 181 rural non-fatal crashes in 2008/09. | Coroner's investigation files and in-depth crash investigations conducted by the CASR. | The majority of fatal (54%) and almost all non-fatal crashes (94%) were designated as system failures. Extreme behaviour was involved in 46% of fatal crashes but rarely implicated in non-fatal injury crashes (3% urban, 9% rural). Illegal system failures contributed to 24% of fatal crashes. |
| Wundersitz & Raftery, 2025. [8] | To update the findings of Wundersitz et al., 2014. | 157 fatal crashes from 2014/15 and 235 injury crashes from 2014-19. | Same as above. | The majority of fatal (70%) and injury crashes (93%) were designated as system failures. Extreme behaviour was involved in 29.9% of fatal crashes but rarely implicated in non-fatal injury crashes (5.1% urban, 9.1% rural). Illegal system failures contributed to 22% of fatal crashes. |
| Raja et al., 2023. [7] | To determine the Safe System factors associated with fatal, and serious and minor injury crashes that occurred in light and other selected vehicles while driving for work. Socio-technical analyses were also conducted. | 300 driving for work crashes (100 each minor and serious- from 2019/20, & fatal injury- from 2011-20). | Traffic crash reports and ACC/ WorkSafe fatality data, and information about vehicle safety ratings, speed, and road risk. | Driving for work injury crashes are often linked to multiple system failures, with failure across more Safe System pillars involved with increasing crash severity. Reckless behaviour was more likely to be triggered in serious (23%) and fatal crashes (20%), compared to minor crashes (11%). |
| Hirsch et al., 2021. [5] | To better understand the system context of pedestrian deaths and serious injuries in New Zealand and develop common crash typologies. Socio-technical analyses were also conducted. | 200 serious injury and 100 fatal crashes involving pedestrians between 2013-17. | Traffic crash reports, and further information about vehicle safety ratings, speed, and road risk and Vehicle Aggressivity Ratings. | Multiple system failures were evident across the majority of fatal (97%) and serious injury crashes (91%), but fatal crashes were more likely to involve more than three pillars of the Safe System. Reckless behaviour was not analysed. |
| Thorne et al., 2020. [11] | To better understand the system context of pedestrian deaths and serious injury in the Auckland region, and the differences between system factors represented in fatal and serious crashes. | 100 serious injury and 12 fatal crashes involving pedestrians in Auckland in 2018. | Same as above. | Multiple system failures were evident in 98.5% of all cases, fatal crashes tended to involve the failure of more pillars than did serious injury crashes, with three or more pillars implicated in 92% of fatal cases compared to 72% for serious injury. Reckless behaviour was not analysed. |
| McTiernan et al., 2019. [10] | To identify factors that contributed to cause and severity of fatal crashes broken down by Safe System pillar and common crash typologies to identify potential countermeasures to close the gaps. | 114 fatal crashes that occurred on the ACT road network between 2007-16. | Traffic crash reports and related data from the Australian Federal Police and Roads ACT. | The top five crash profiles were motorcycles, often inexperienced riders (30%), run-off road involving non-frangible roadside hazards (21%), intersection crashes (19%), head on crashes (13%), and pedestrian crashes (12%) in areas about Safe System speeds for VRUs. |

# 4. FINDINGS - SAFE SYSTEM DESCRIPTIVE ANALYSIS

This section firstly presents the crash samples and geographical/temporal trends, followed by an analysis of the involvement of the Safe System pillars and the related contributing factors. Finally, a summary of the implication of system failure and reckless/extreme behaviour in the fatal crash samples is presented.

## 4.1. Overview of crashes included in the study

Table 2 summarises all road users/vehicle types included in the overall sample and each cohort, as described in the method section. The 'light vehicle only' crashes cohort by design consists of only light vehicle single or multiple vehicle crashes. In contrast, the 'all other' crashes cohort is more varied, with most crashes still involving a light vehicle, but also a wide range of other road users. Motorcycles and trucks were frequently involved in these crashes, with pedestrians also regularly implicated.

*Table 2: Involvements of all crash participants by road user/vehicle type in the overall sample and by crash cohort.*

| Road User/Vehicle Type | Overall crashes sample (n=200) | Light vehicle only crashes (n=100) | All other crashes (n=100) |
|---|---|---|---|
| Light Vehicle (car, SUV, ute, van) | 214 (66.2%) | 144 (100%) | 70 (39.1%) |
| Truck/Heavy Truck | 36 (11.4%) | - | 36 (20.1%) |
| Bus | 8 (2.5%) | - | 8 (4.5%) |
| Motorcycle/Moped | 42 (13.0%) | - | 42 (23.5%) |
| Pedestrian | 19 (5.8%) | - | 19 (10.6%) |
| Cyclist | 4 (1.1%) | - | 4 (2.2%) |
| **Total** | **323 (100%)** | **144 (100%)** | **179 (100%)** |

The vehicle movements coded for each crash differ between cohorts. However, loss of control/run off road and head on movements were predominant across the sample (Figure 8). Loss of control/run off road and head on crashes comprised 83% of the movements in light vehicle only crashes. Whereas for all other crashes, loss of control/run off road and head on comprised 48%, crossing/turning movements were involved in 25%, and pedestrian crashes comprised 17%. Overtaking/lane changing and rear end movements were less common in both cohorts.

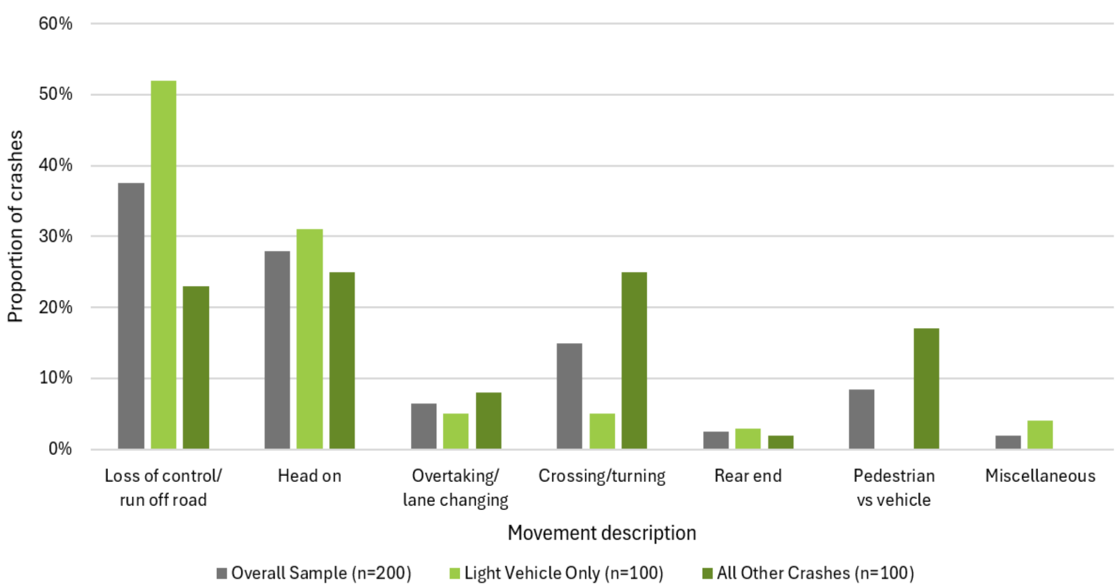



*Figure 8: Crash movements involved in the overall sample of crashes and by crash cohort.*

## 4.2. Geographical and temporal patterns

Figure 9 shows the distribution of the fatal crashes in the dataset across the regions of New Zealand. The Waikato region had the highest proportion of all crashes (18%), reflecting a high proportion of traffic on rural roads, followed by Auckland (13%), Canterbury (12%), and Northland/Manawatu-Whanganui (11%). The crashes in the 'light vehicle only' cohort showed approximately the same pattern as the whole sample, while the 'all other' cohort was more clustered around Auckland, Waikato, and the Central North Island. It is worth noting that these figures are absolute number of fatal crashes for the region, and not relative to population density of the region.

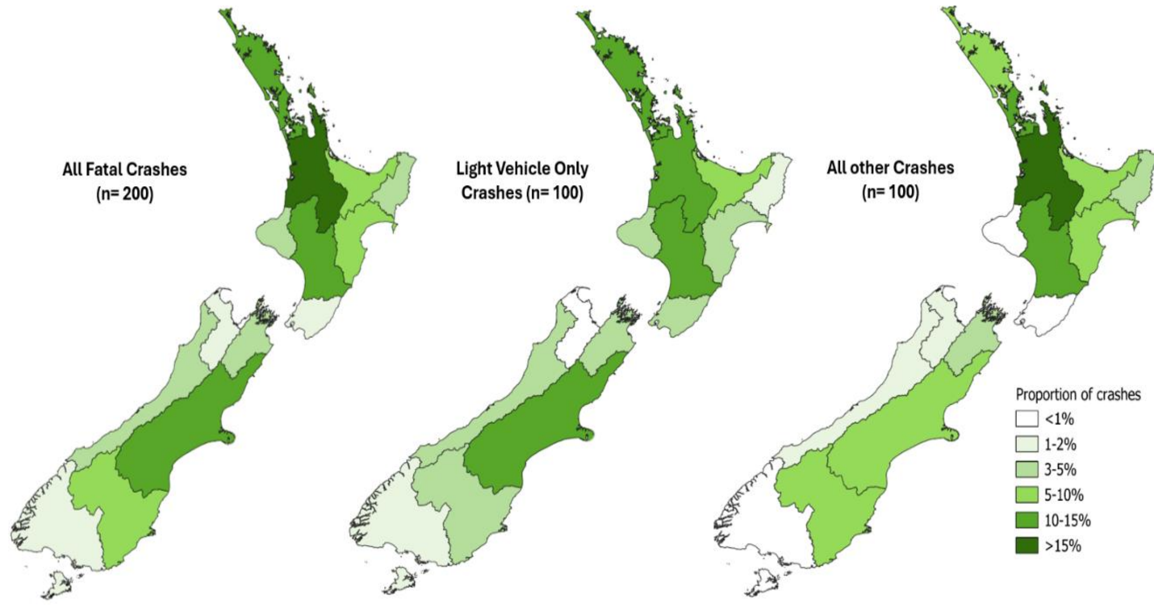



*Figure 9: Proportion of crashes in each region of New Zealand for the overall sample and by cohort.*

Crashes occurred in a relatively uniform pattern throughout the year, except for a significant peak in the summer months, particularly in the December/January period (Figure 10). Possible reasons for this might be more road use in these months and there were no obvious trends suggesting greater prevalence of reckless/illegal behaviour. Further analysis might seek to understand other reasons why there are more fatal crashes in December and January.

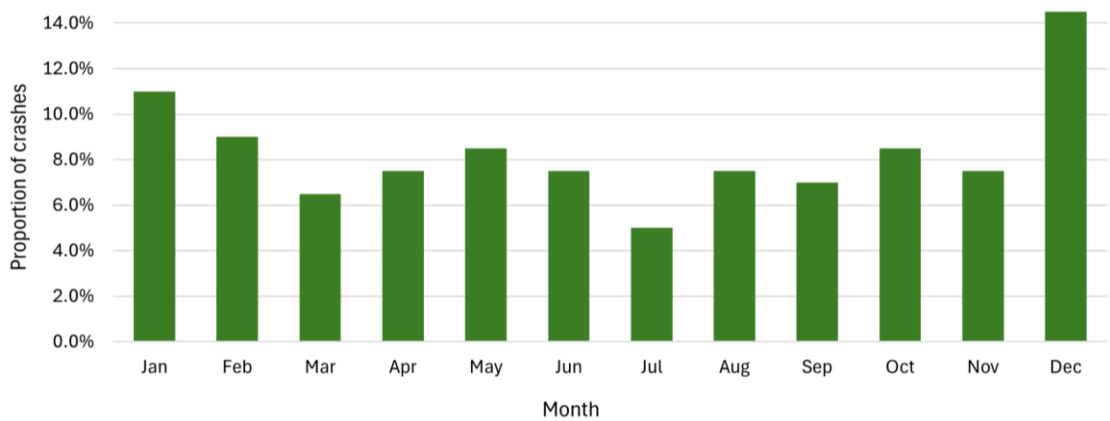



*Figure 10: Proportion of crashes by month for the overall sample.*

Crashes occurred mainly during daylight hours reflecting when most travel happens, particularly between 9 am to 6 pm, peaking between 2 pm to 4 pm in the afternoon (Figure 11). There was also an evening peak between 7 pm to 10 pm and fewer crashes overnight. It is notable however that 12% of crashes occurred between 11pm and 6am.

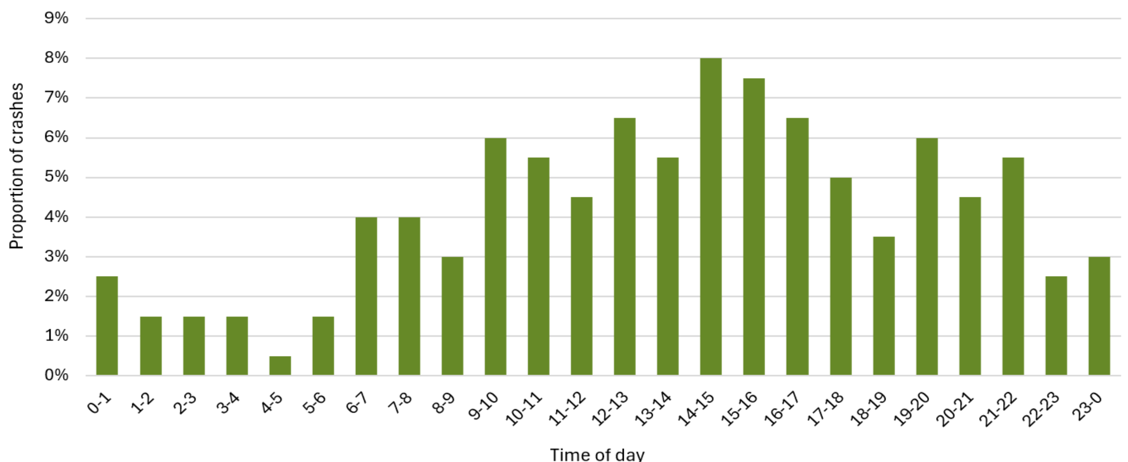



*Figure 11: Proportion of crashes by time of day for the overall sample.*

## 4.3. Safe System pillar involvement

Central to this analysis was to assess how failures across Safe System pillars have combined to cause fatal crashes. Figure 12 shows the proportion of crashes in which each Safe System pillar was triggered in the whole sample and each crash cohort. The user pillar was always triggered, consistent with previous Safe System analyses and research which indicated that 90-95% of crashes result from human error [6,7,29]. However, the other pillars were also triggered in more than 70% of crashes each, demonstrating the importance of looking beyond users, to failures in the wider system.

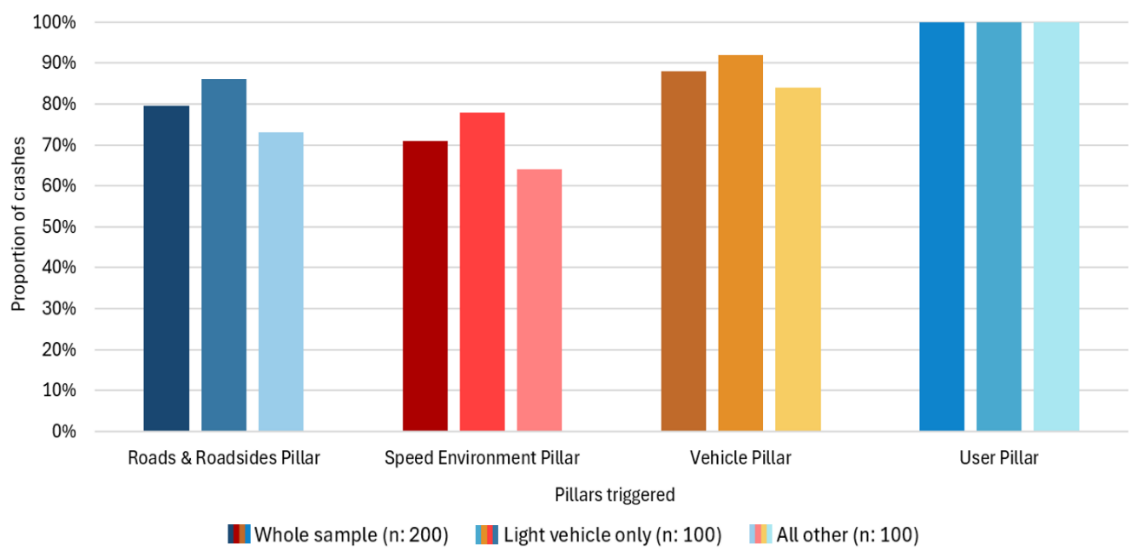



*Figure 12: Proportion of crashes involving each Safe System pillar overall (left bar for each pillar) and by crash cohort- light vehicle only crashes (middle bar), and other crashes (right bar).*

It's important to note that pillar failures may be present in crashes but may not always contribute to the cause or consequence of the crash as much as other factors. However, a deeper investigation of the relative contribution of factors to crash likelihood or outcome is outside the scope of this work.

Overall, 99% of the fatal crashes in the sample involved multiple system failures, with 56% involving failures in all four Safe System pillars (Figure 13). The 'all other crashes' cohort consistently had a higher proportion of crashes triggering 1-3 pillars than 'light vehicle only' crashes, which had a higher proportion of all four pillars involved in crashes. This may indicate that crashes involving a wide range of users including pedestrians, cyclists, motorcyclists, and trucks require less to 'go wrong' to result in a fatality, particularly crashes involving VRUs.

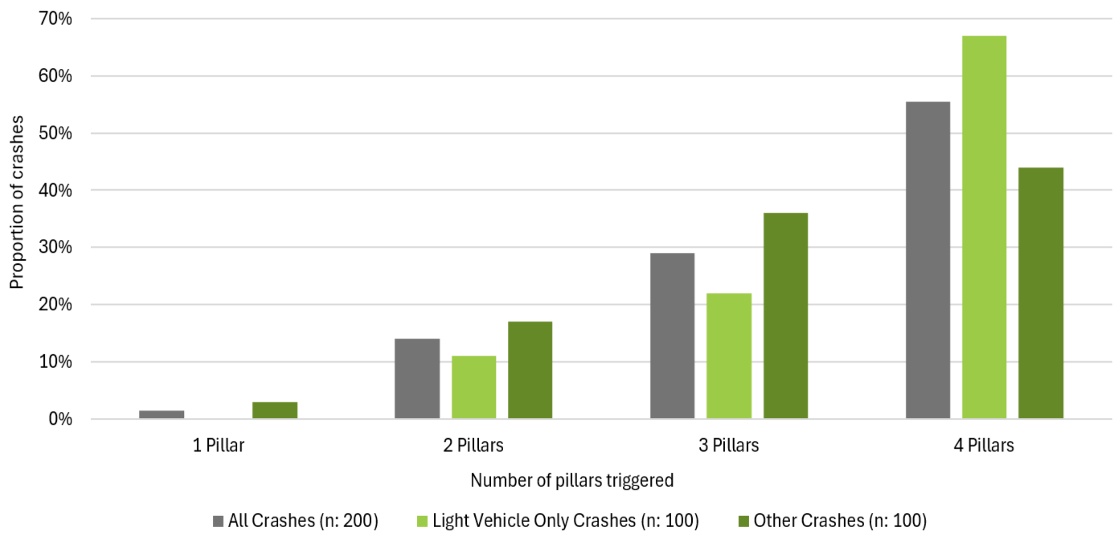
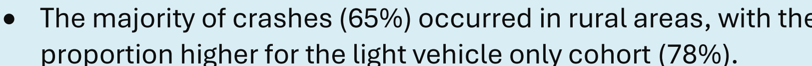



*Figure 13: Proportion of crashes triggering multiple Safe System pillars overall and by crash cohort.*

## 4.4. Roads and roadsides pillar

**Highlights- roads and roadsides pillar**



- The majority of crashes (65%) occurred in rural areas, with the proportion higher for the light vehicle only cohort (78%).
- Half of fatal crashes involved a vehicle leaving the lane on a >80 km/h rural road that was undivided or lacked roadside barriers.
- While there were only 23 crashes involving pedestrians and cyclists, 63% involved a lack of infrastructure or adequate safety features.

The roads and roadsides pillar covers factors in the physical environment where the crashes occurred. Figure 14 summarises the land use around the crash location and shows that the majority of crashes occurred in rural areas (65%), with fewer occurring in urban/commercial (28%) and transit corridors (7%), which is to be expected given the focus on fatal crashes. Of those that occurred in rural areas, a substantial segment occurred in rural residential areas, likely due to the combination of high speeds with more vehicle traffic than remote areas. The 'light vehicle only' cohort had a higher proportion of crashes occurring on rural roads (78%), while 'all other crashes' had a greater proportion occurring in urban/commercial areas (37%) compared with the 'light vehicle only' cohort.

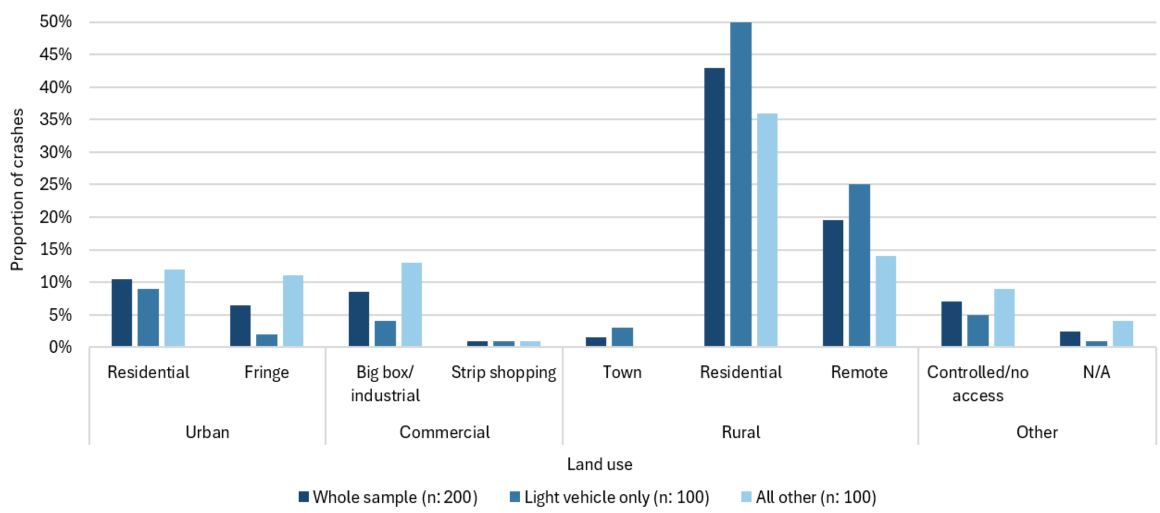



*Figure 14: Land use – proportion of crashes by whole sample and each crash cohort.*

Analysis by road type based on the One Network Framework found that almost half (45%) of crashes occurred on rural/peri-urban roads and connectors. Other common road types were interregional connectors (26%), urban connectors (15%), and urban streets (9%).[5]

Most crashes occurred mid-block (79%), with 18% occurring at intersections, and 3% at driveways. There was a higher proportion of intersection crashes in the 'all other' cohort (28%) than in 'light vehicle only' crashes (9%). Of all the intersection crashes, 19 were T or Y junctions, 14 were crossroads, and two were roundabouts. In terms of traffic control, 23 were give way, 12 were stop signs, and two were traffic signal controlled.

[5] Urban streets includes activity, main, and local streets.

Figure 15 displays the crash factors which triggered the roads and roadsides pillar, and how frequently they were implicated. The most common trigger was vehicles leaving the lane on rural roads that were undivided or lacked roadside barriers and had speed limits greater than 80 km/h (50%).[6] This proportion was even greater for 'light vehicle only' crashes (61%). In these crashes there is a mismatch between the speed and physical environments, resulting in more severe outcomes as the traffic is unprotected from other vehicles and roadside objects above a survivable speed.

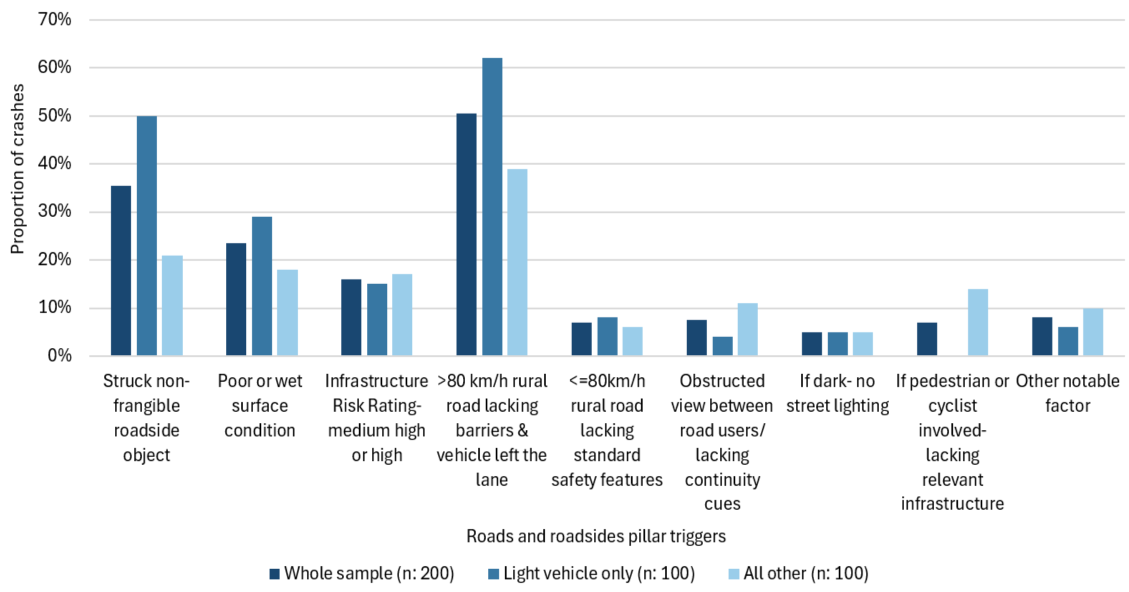



*Figure 15: Roads and roadsides pillar triggers – proportion of crashes activating each trigger by whole sample and each crash cohort.*

Vehicles commonly struck non-frangible roadside objects (36% of crashes), particularly in light vehicle only crashes (50% of crashes). This highlights the lack of protection at roadsides on New Zealand roads. Common objects struck include trees, ditches/ drainage, embankments, power poles and lamp/signposts.

Poor or wet surface condition was also a frequent contributor (24% of crashes), with most of these cases resulting from wet roads (83%). The poor surface conditions at crash locations included loose material (4), flushing/bleeding (3), ice/snow (1), and potholes (1). As mentioned earlier, within this analysis we are not able to determine whether wet weather was incidental to the crash (it often rains in New Zealand), or whether it was a contributing factor through lack of surface friction, or reduced visibility.

Infrastructure Risk Ratings (IRR) of high or medium high, were implicated in 16% of all crashes, indicating that they occurred on road corridors with a known level of road safety risk. This shows the limitation of using predictive models for assessing risk of the most severe crashes. A smaller proportion of crashes (6%) occurred on 60 to 80 km/h rural roads lacking any one of the following standard rural road safety features: a sealed shoulder at least 0.5m, audio tactile line markings, fog/edge lines.

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[6] The missing barrier had to be relevant to the crash outcome, i.e. no roadside barriers and the vehicle ran off the road or undivided and the vehicle crossed the centreline.

Poor visibility of the road ahead or between road users was also a contributing factor that featured less frequently (13%). Lack of street lighting at night in urban areas, motorways, and rural intersections was implicated in 5% of crashes. Other causes of obstructed view were involved in 8% of crash cases. Reasons for blocked view included parked cars, blind corners/brow of hill, and a lack of continuity cues through intersections, often crossroads, and other causes.

Of the 22 crashes that involved pedestrians and cyclists, 14 (63%) involved a lack of infrastructure or adequate safety features. Eight of these were crashes where the pedestrian was crossing the road in a location without crossing facilities or adequate safety features,[7] four involved a pedestrian walking on a road without a footpath, and two involved a cyclist travelling on a road without cycling infrastructure.

Other notable roads and roadsides factors that triggered the pillar included roadworks at the crash location (4), sunstrike (3), very windy conditions on a bridge (1), right turning vehicle stopped on road without right turn bay (2), missing road markings (1), and a parked truck stated to not have been displaying appropriate marker lights (1).

## 4.5. Speed environment pillar

**Highlights- speed environment pillar**

- Half of the fatal crashes were on >80km roads without barriers suggesting a mismatch between the road and speed environment.
- 45% of fatal crashes occurred on roads where the mean operating speed (average speed of vehicles travelling on the road) was significantly lower than the posted speed limit.

The speed environment pillar covers the way that roads are set up with regard to speed, including posted speed limits, the mean operating speed (MOS) of vehicles as defined in MegaMaps (a proxy for the ‘natural’ speed of the road), missing infrastructure required for safe road use at higher speeds, and the presence of VRUs.

Figure 16 summarises the speed limits at the fatal crash locations. Most crashes occurred on 100 km/h roads (default speed for rural roads), particularly ‘light vehicle only’ crashes, which is to be expected given it is above a survivable collision speed. The next highest proportion of crashes occurred on 50 km/h roads (default speed for urban roads), particularly for the ‘other crashes’ cohort, as it is above a survivable speed for VRUs. Fewer crashes occurred at other speed limits, likely as they are used in fewer locations, but could also be that the lower speed limits allow a greater margin for error and lower crash energy resulting in less severe outcomes.

[7] Adequate crossing infrastructure safety features included signalised or raised pedestrian crossings.

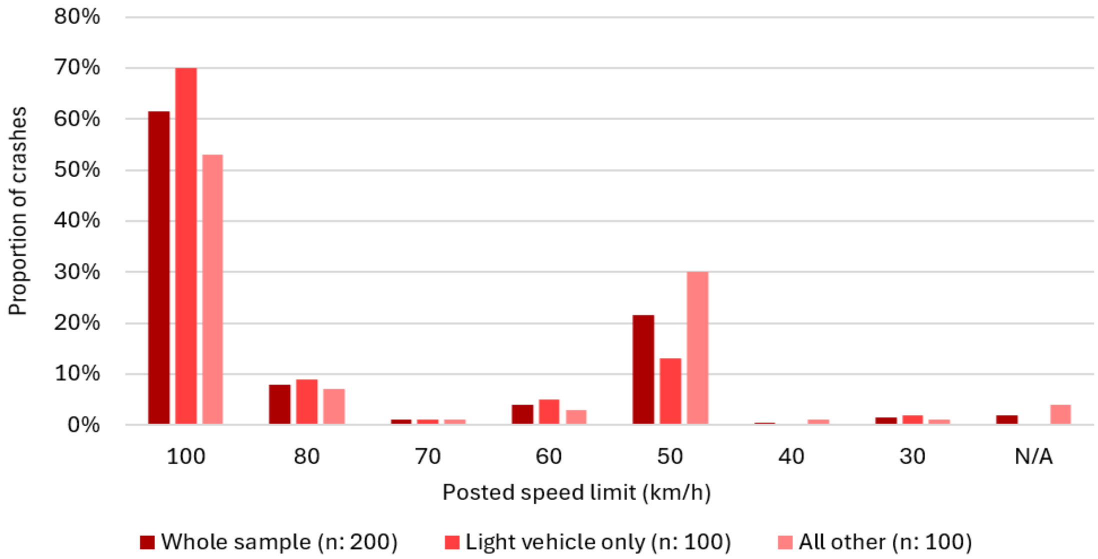



*Figure 16: Posted speed limit- proportion of crashes by whole sample and crash cohort.*

The most common speed environment trigger, as with the roads and roadsides pillar, was vehicles leaving the lane on rural roads with a speed limit of greater than 80 km/h that were also undivided or lacked roadside barriers (Figure 17). This contributing factor was included in both pillars because it has joint causes in the physical and speed environment where the mismatch leads to hazardous situations. Solutions may also come from road infrastructure or speed limit changes.

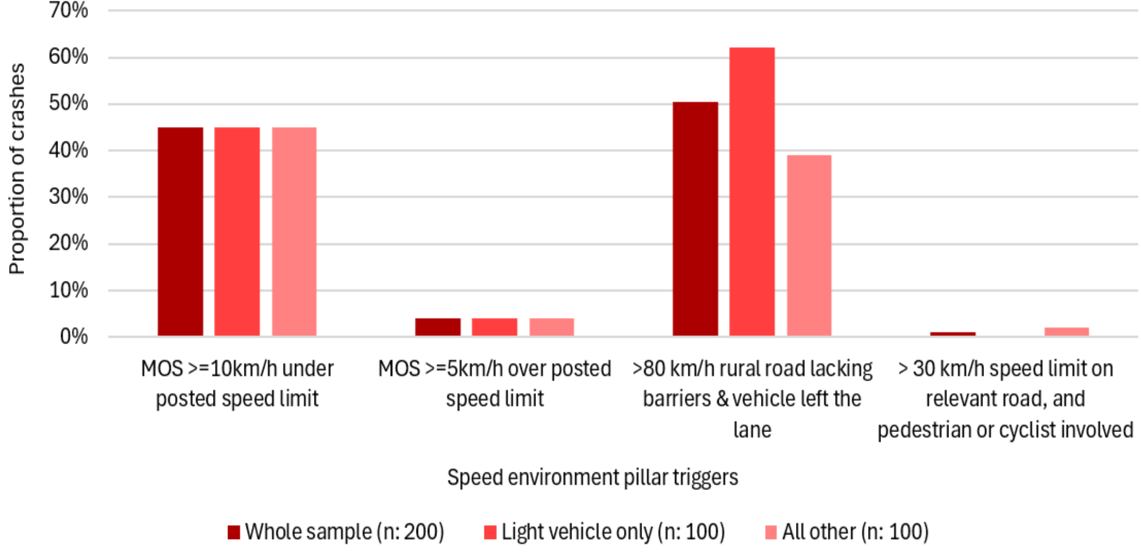



*Figure 17: Speed environment pillar triggers – proportion of crashes activating each trigger by whole sample and crash cohort.*

Similarly, two crashes involved pedestrian/cyclists on local and main streets with posted speed limits above 30 km/h, which is above a survivable speed for VRUs. However, of the total 22 pedestrian/cyclist crashes, only three occurred on local and main streets, while the remainder occurred on urban arterial roads, rural roads, or driveways.

Comparing the posted speed limit to the MOS of vehicles travelling on the road corridor allows analysis to determine the appropriateness of speed limits by what drivers feel is an appropriate speed for the road based on how it looks and feels (how the road 'self explains'). In 45% of crashes, the MOS was >=10 km/h under the posted speed limit indicating the posted speed limit is too high for the road environment since the 'average driver' travels significantly slower than the speed limit for the road. Conversely, 4% were >= 5 km/h over the speed limit indicating the road environment is perceived by drivers to be faster than the posted speed limit.

Figure 18 shows the distribution of MOS on 80 km/h and 100 km/h roads where the sample fatal crashes occurred. This shows that 44% of 100 km/h and 32% of 80 km/h roads had MOS of >=10 km/h under the speed limit. These distributions have a long tail to the left, suggesting that fatal crashes often occur on roads with inappropriate speed environments, where the posted speed limit doesn't align with the road environment (often windy and narrow rural roads). Interestingly, 19% of fatal crashes on 80 km/h roads has MOS of >=5 km/h over the speed limit, suggesting the road felt faster than 80 km/h in these instances.

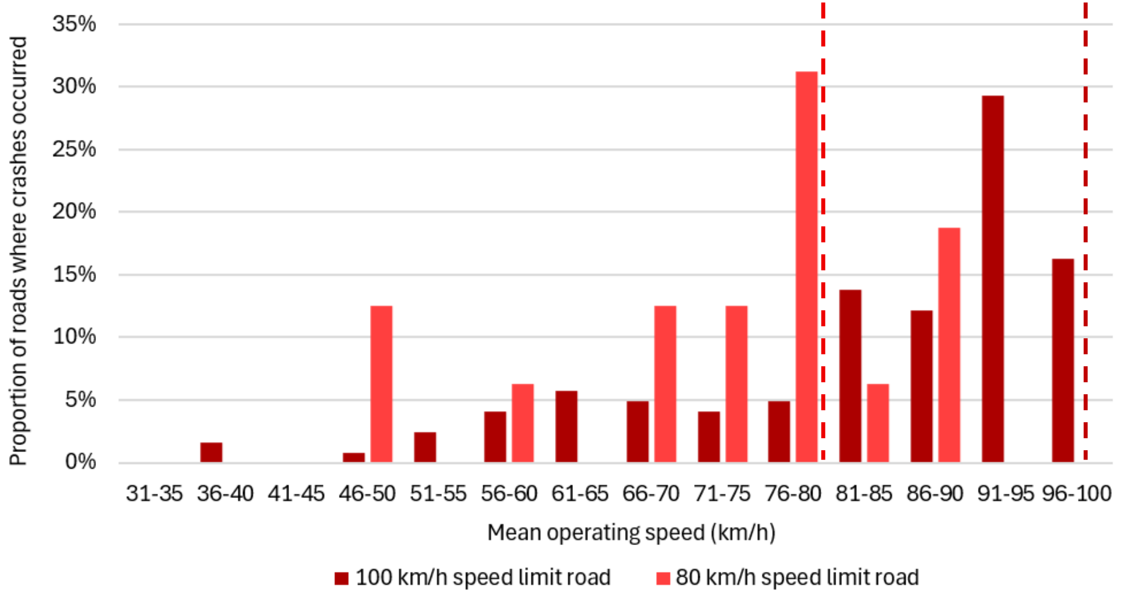
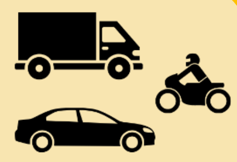



*Figure 18: Mean operating speed at crash locations on 100 km/h and 80 km/h speed limit roads.*

Comparing the MOS of all 100 km/h roads from the 2024 National Speed Survey (90.7 km/h) to the MOS of those 100 km/h roads in which the sampled fatal crashes occurred (83.8 km/h) shows that fatal crashes occurred on roads with significantly slower operating speeds. In such circumstances it may be easier to travel too fast for the conditions (e.g. winding road) and in fact we found that in 37% of all crashes, motorists were recorded as doing so. Of the 100 km/h roads where fatal crashes occurred, 28% had MOS less than 70 km/h, with the lowest operating speed recorded being 36 km/h.

## 4.6. Vehicle pillar

**Highlights- vehicle pillar**



- Vehicles driven by the victim were on average older than the NZ light vehicle fleet, often had low safety ratings and were missing basic (ABS or ESC) and advanced safety features.
- In crashes involving multiple vehicles, the victim's vehicle was always of equal or lesser weight to the colliding vehicle.
- 70% of vehicles involved in collisions with VRUs had poor VRU protection safety ratings (1-3 stars).

The vehicle pillar covers factors related to the type, size, design, and condition of the vehicles involved in each crash, and interactions with other vehicles and road users.

Figure 19 depicts the vehicles involved in the fatal crashes included in this study by the proportion of victim's vehicle (top) and colliding vehicle (bottom). Of the crashes involving only vehicles, 58% involved multiple vehicles and the remainder were single vehicle crashes. In multi-vehicle crashes, cars were the vehicle in which the fatality occurred in 68% of crashes, while larger light vehicles (24%), and trucks/buses (8%) were involved less frequently. In each of these crashes, the victim's vehicle was almost always either an equal or lighter weight than the colliding vehicle. This is why when trucks and buses were involved in fatal crashes, they were almost always the colliding vehicle.

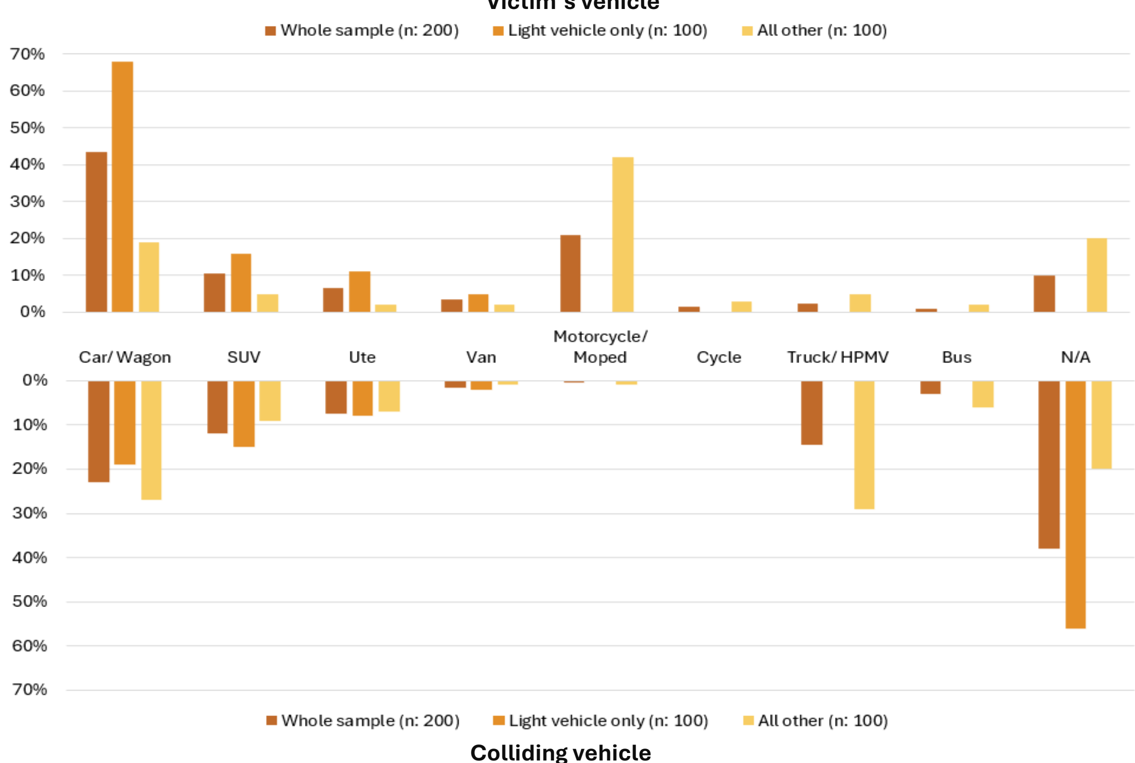



*Figure 19: Vehicle type for victim's vehicle (top) and colliding vehicles (bottom) – proportion of vehicles for the whole sample and by crash cohort. N/A means no vehicle involved. In the victim's vehicle graph N/A means that the victim was a pedestrian, while in the colliding vehicle graph it means that no colliding vehicle was present (i.e. it was a single vehicle crash).*

Likewise, in crashes involving cars and VRUs (motorcyclists, cyclists, and pedestrians), the VRU was always the victim due to the lack of protection that their mode of transport offers in the event of a collision.

Figure 20 shows the age distribution of victim's and colliding vehicles. The mean age of the victim's vehicle was 15.2 years old (16.5 years old for 'light vehicle only' cohort), with a fifth of these vehicles over 20 years old. Meanwhile the average colliding vehicle age is significantly lower than victim's vehicles at 11.5 years old (11.2 years old for 'light vehicle only' cohort). In comparison, the average age of the New Zealand light vehicle fleet, as of 2024, is 14.8 years old and has been gradually increasing over the past 25 years [30]. Older vehicles tend to lack safety features and be smaller than modern versions hence, all else being equal, when a collision occurs, the older vehicle is more likely to experience severe outcomes.

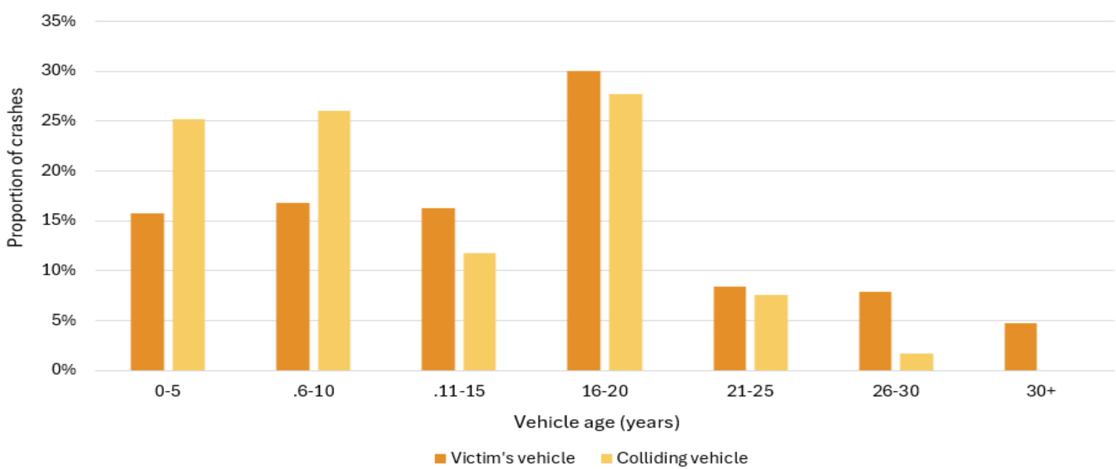



*Figure 20: Vehicle age among the light vehicle crashes cohort (n= 100)– proportion of crashes by vehicles' role in the crash.*

The frequency of each contributing factor trigger for the vehicle pillar is displayed in Figure 21 below. Except where otherwise specified in the figure, the pillar triggers relate to the victim's vehicle. Missing advanced vehicle features were also relevant to crashes where a vehicle struck a VRU (e.g. automatic braking systems that detect VRUs).

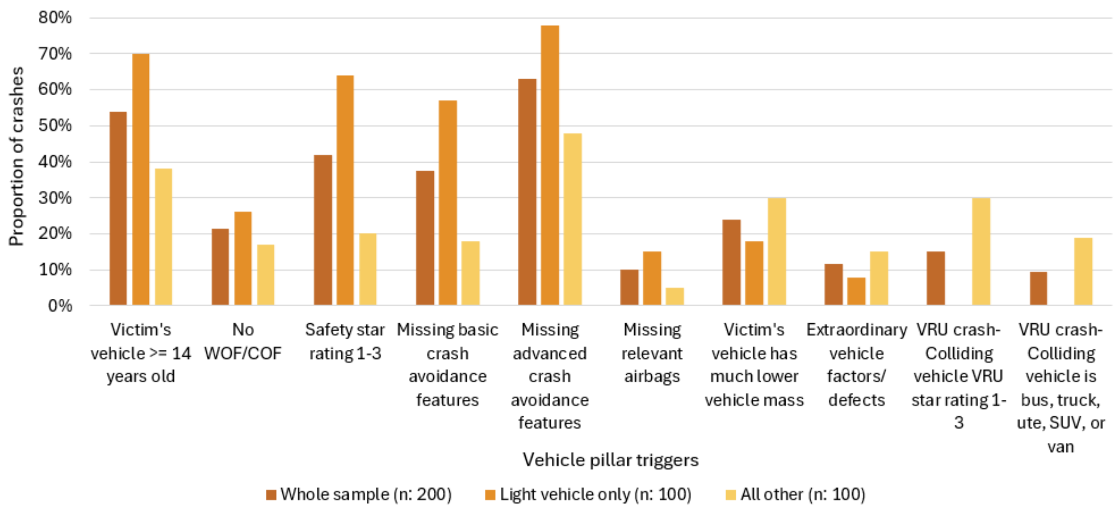



*Figure 21: Vehicle pillar triggers – proportion of crashes activating each trigger for the whole sample and by crash cohort.*

As mentioned previously, the age of the victim's vehicle was often a factor in crashes. Where the victim's vehicle was of an equal or greater age than the fleet average, this triggered the pillar (54% of crashes), and this was particularly frequent in the 'light vehicle only' crash cohort (70% of crashes). The victim's vehicle was also of much lower mass than the colliding vehicle in 24% of crashes.

The vehicle driven by the victim of the crash also tended to be missing safety features. Basic crash avoidance features, defined as automatic braking systems (ABS) and electronic stability control (ESC) which are standard features in modern cars were missing in the victim's vehicle in 38% of crashes (57% for the 'light vehicle only' cohort). Also, in 10% of crashes (15% for the 'light vehicle only' cohort), airbags were missing in areas of the car that would protect the victim in the event of a crash.

The presence of advanced crash avoidance features which are often present in newer vehicles was assessed when it was relevant to the crash. Such technologies and circumstances in which they were deemed relevant included:

- Lane keep assist technologies, when a vehicle left its lane, either across the centreline or off the road to the left.
- Autonomous emergency braking if the crash involved occurred at 50 km/h or less (city version), 80 km/h or less (interurban version), or if the vehicle hit a VRU (VRU detection version).
- Blind spot warning systems in crashes where a vehicle hit another vehicle or VRU while turning or changing lane.
- Reversing cameras if a vehicle hit a pedestrian or cyclist while reversing.

A significant proportion of vehicles involved in fatal crashes were missing such features when they were relevant to the crash circumstances (63% of crashes), particularly for 'light vehicle only' crashes (78% of crashes).

Collectively the contributing factors mentioned earlier, and other features, affect the vehicle safety rating. Figure 22 summarises the distribution of overall vehicle safety star ratings of the victim's vehicles involved in fatal crashes for the 'light vehicle only' cohort only. The rating was three stars or less in 42% of crashes (64% in the light vehicle only cohort). A greater proportion of victim's vehicles had 2 or 3 stars than other ratings.

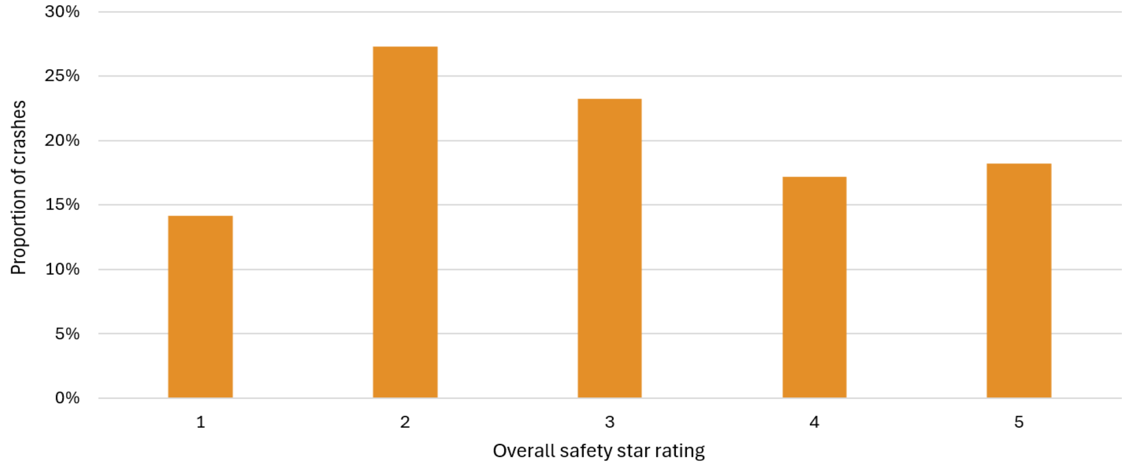



*Figure 22: Victim's overall vehicle safety star rating in the light vehicle crashes cohort (n= 100) by proportion of crashes.*

In a notable proportion of crashes, there were issues with the upkeep or vehicle failures implicated. The victim's vehicle was missing a WoF/CoF in 22% of crashes. Further, extraordinary vehicle factors were present in 12% of crashes. Examples of these included issues with tyres (e.g., very low tread or blowouts), but also vehicle misfunctions (e.g. a faulty accelerator), and factors which affected the drivers' perception of other road users (e.g. items in vehicle blocking visibility, or misfunctioning sensors).

Of crashes involving VRUs, the vehicle safety rating related to VRU protection was three stars or lower in 70% of crashes (15% of all crashes). Meanwhile in 43% of these crashes (10% of all crashes) the vehicle type was identified as high-risk to VRUs (i.e. trucks, buses, utes, SUVs, and vans) due to having features such as high/flat bonnet shapes and/or large mass which increase the severity of outcomes for VRUs in the event of a collision.

## 4.7. User pillar

**Highlights- user pillar**

- 45% of the crashes involved drivers on their learner, restricted, or overseas license, or driving illegally (e.g. without a license, while disqualified, etc.)
- 57% of crashes involved a road user with alcohol over the legal limit, or illegal/ pharmaceutical drugs that affect driving.
- 47% of crashes involved a road user speeding by greater than 10 km/h or travelling too fast for the conditions.
- 40% of crashes involved distraction or inattention from a road user involved.
- In 34% of 'light vehicle only' crashes, the victim was not wearing a seatbelt.

The user pillar pertains to characteristics, conditions, and behaviours of the individual road users involved in the crash. Speed behaviour is included in this pillar, which is distinct from speed environments in the Speed pillar.

Figure 23 summarises the distribution of ages of the driver of the victim's vehicle or VRU when they were the victim (hereon called the victim) and that of the colliding vehicle.

While the average age of these two groups was similar (victim= 44 years old, colliding vehicle= 45 years old), the distribution of the victim's age is skewed towards younger road users. This is particularly stark in the 'light vehicle only' cohort, where the driver of the victim's vehicle was 25 years or younger in 32% of cases. This departs from the age distribution of New Zealand licensed drivers which approximately follows a normal distribution, skewed towards older drivers [31].

The driver of the vehicle in which the fatality occurred was male in 76% of cases, and similarly the colliding vehicle driver was male in 73% of crashes. This suggests the males are over-represented in crash involvement overall, and not only in fatalities. However, this may just reflect that males do more driving, particularly in rural areas.

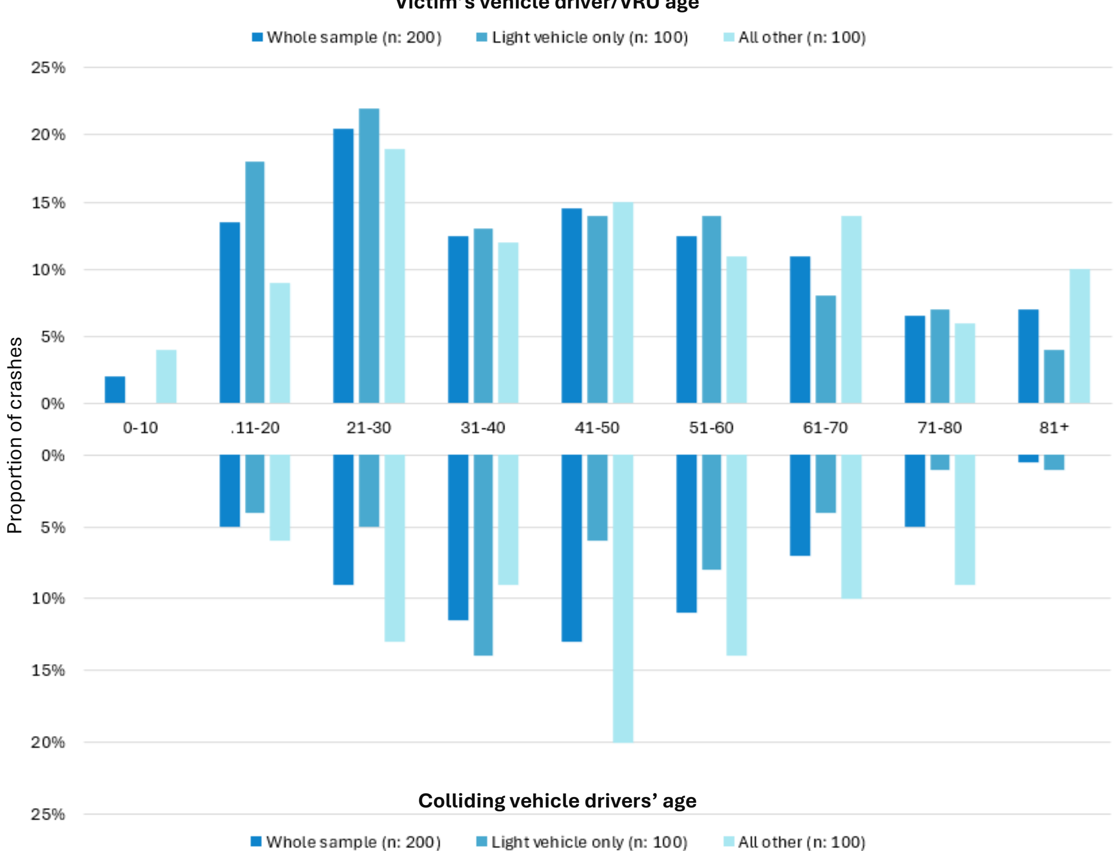



*Figure 24: Distribution of victim's vehicle driver/VRU age (top) and colliding vehicle drivers' age (bottom) – proportion of crashes for the whole sample and by crash cohort.*

Since there was a significant number of user pillar triggers, these will be presented in groups of related contributing factors below. Firstly, factors related to road users' age and license type are displayed in Figure 24.

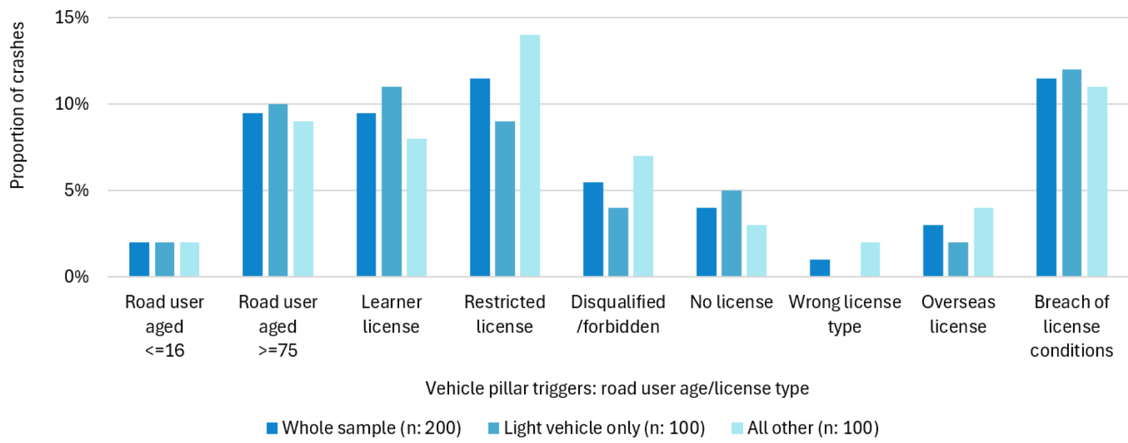



*Figure 23: User pillar triggers: driver age and license type – proportion of crashes activating each trigger for the whole sample and by crash cohort.*

Involvement of road users at either end of the extremes of the age distribution triggered the user pillar. Older road users aged 75 years and older were involved in approximately 10% of fatal crashes, most often as the driver of a vehicle, but also in fewer cases as pedestrians. A small proportion of the road users involved were 16 years old or younger

and were either unlicensed drivers (‘light vehicle only’ cohort) or young children struck by a vehicle in a driveway (‘all other’ crashes cohort).

In total, one of the license-related contributing factors was triggered in 45% of fatal crashes. Of the crashes involving license triggers, 30% the road users were compliant with license conditions but were on a learner, restricted, or overseas license, possibly indicating that their inexperience with NZ driving conditions could have played a role in the crash. Because younger people were over-represented in the crashes, there may be other factors (such as attitude) associated with younger people who also happen to be on a learner or restricted license. However, in 70% of these crashes, users were either in breach of license conditions, did not have a license to operate the vehicle,[8] or were disqualified/forbidden from driving. Notably of the learner/restricted license drivers involved in fatal crashes, 47% were in breach of their license conditions, and featured markedly in rural single vehicle run-off road and multi-vehicle crashes, as discussed later.

Impairment and inattention were frequently implicated in fatal crashes (Figure 25). 57% of all crashes involved intoxication in one or more of the road users, with the proportion higher in ‘light vehicle only’ crashes.[9] In some cases alcohol and drugs, or multiple types of drugs were present in the same user.

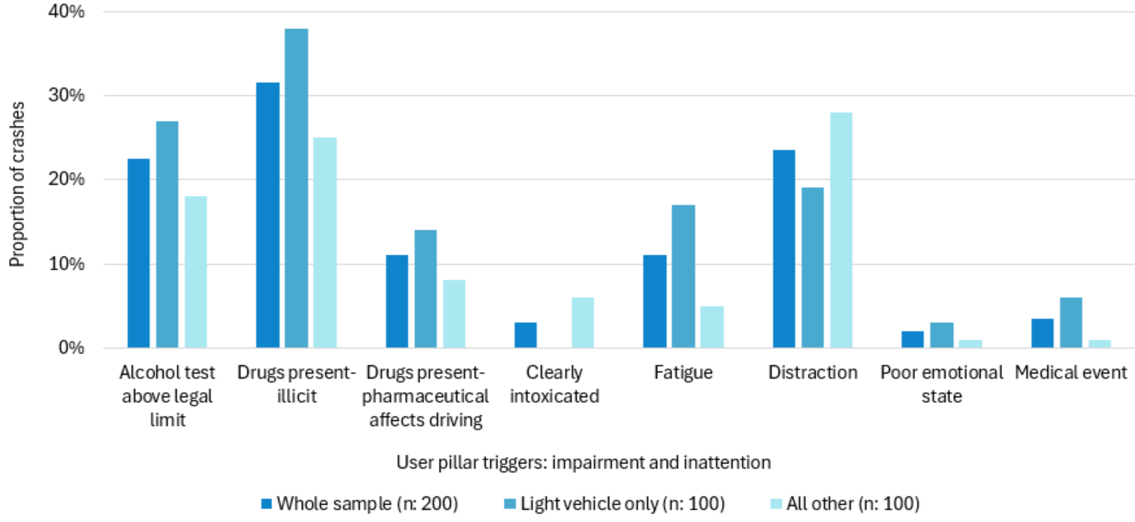



*Figure 25: User pillar triggers: impairment and inattention – proportion of crashes activating each trigger for the whole sample and by crash cohort.*

Alcohol over the legal limit was implicated in 23% of all crashes, with most cases involving users over the standard limit (50 mg/ml of blood or 250 mcg/L for breath tests), and a smaller proportion involving road users under 20 years old with alcohol present (3% of all crashes). Illicit drugs were present in 32% of crashes, while pharmaceutical drugs which affect driving were implicated in 11%. As the CAS doesn’t report whether users who were not driving a vehicle were intoxicated, the ‘clearly intoxicated’ category was added to capture circumstances where intoxication was noted for pedestrians and cyclists in the crash comments. This was triggered in five crashes, all involving intoxicated pedestrians.

[8] This includes no license and wrong license class which in all cases were motorcyclists with a Class 1 license to operate light vehicles, but not the required Class 6 motorcycle license.
[9] We report whether drugs were present or not in road users involved in the crash, but do not know whether they were intoxicated at the time of the crash.

While there are considerable limitations with accurately capturing distraction and inattention in TCRs, distraction and/or inattention was coded in 40% of all crashes, with distraction most frequently implicated (24% of all crashes). In most cases the crash report noted distraction as a factor, but didn't provide the reason, or just stated that the driver was not concentrating/inattentive. When specific causes were noted, they included using a mobile phone (5 crashes), distracted by a passenger (5 crashes), looked but did not see a VRU (5 crashes), or other causes e.g. racing another vehicle (3 crashes). 'Looked by did not see' is a cognitive phenomenon where the driver may be actively looking in a specific direction, but their brain still fails to process or register the presence of another road user due to misinterpretation, lapses, or expectations failures. We have grouped in with distraction/inattention due to the similarity of crash mechanism.

Regarding inattention, fatigue was involved in 11% of cases. Most of these cases involved a driver having reported poor sleep, having done long drives, or not taking breaks from driving, while in three crashes the driver fell asleep at the wheel. A road user was in a poor emotional state in 2% of cases, most often following an argument/confrontation, with one case involving road rage. A further 4% of cases involved an acute medical event. Travelling with significant speed (>=10 km/h over the speed limit/MOS), or too fast for the conditions was involved in 47% of all fatal crashes (Figure 26). Interestingly, of the crashes involving speeding (25% of all crashes), two thirds involved extreme speed, travelling 20 km/h or more over the MOS/posted speed limit.

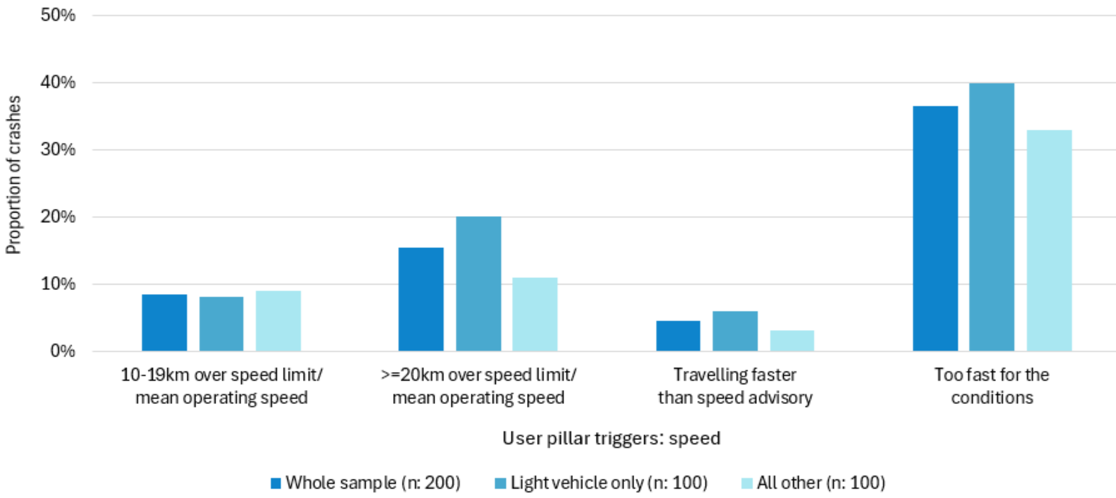



*Figure 26: User pillar triggers: speed- proportion of crashes activating each trigger for the whole sample and by crash cohort.*

Travelling too fast for the conditions was reported in 37% of crashes. This is often noted in the crash report when the vehicle speed is unknown, but investigators deemed speed to be implicated in the crash circumstances. In 5% of all crashes, a vehicle was travelling faster than the speed advisory for a corner, often resulting in loss of control crashes.

Figure 27 summarises the contributing factors related to driver behaviours involved in the circumstances leading up to the crash. Crash movements that were commonly involved in all crashes included inadvertently crossing the centreline (37%), losing control of the vehicle (32%), running off the road to the left (18%), and red light running/failure to give way/stop (10%).

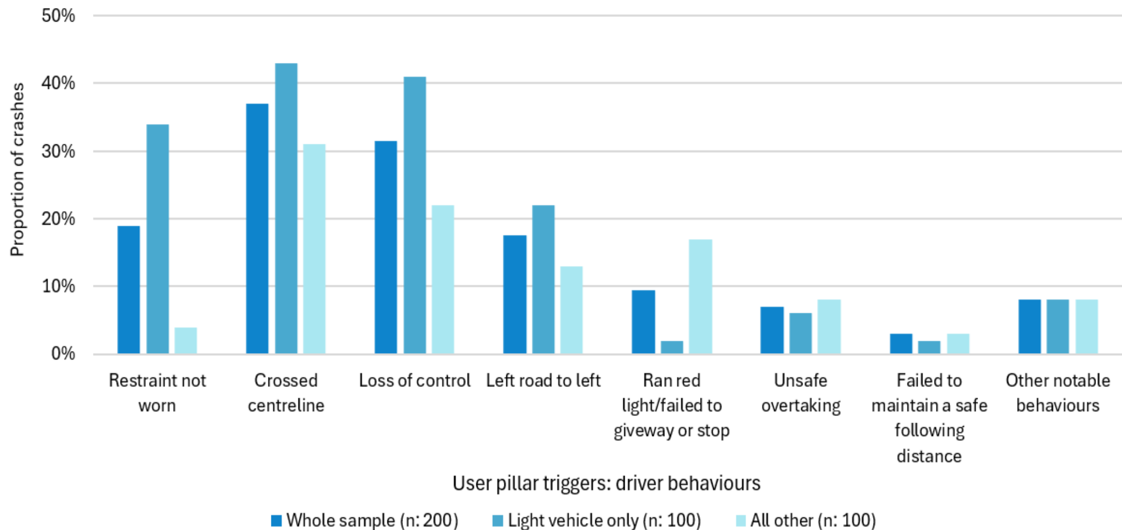



*Figure 27: User pillar triggers: driver behaviours- proportion of crashes activating each trigger for the whole sample and by crash cohort.*

Other behaviours suggesting recklessness include seatbelt non-use (19% of all crashes, but 34% of the 'light vehicle only' cohort), unsafe overtaking (7% of all crashes), failing to maintain a safe following distance (2% of 'all crashes), and other notable behaviours (8% of all crashes). Examples of other notable behaviours included reckless driving (e.g. racing or being involved in a police chase), driving with passengers outside of the vehicle, and walking on the edge of a high-speed rural road at night wearing dark clothing.

Notably some behaviours were often associated with each other. For example, in 76% of crashes involving seatbelt non-use, alcohol over the limit or drugs were present.

Lastly, Figure 28 covers the pillar triggers related to VRU crashes. The most common factor was insufficient checks of surroundings by either the colliding vehicle or VRU resulting in the crash (10% of all crashes). Other VRU factors were not commonly implicated, all being involved in 3% or fewer of all crashes.

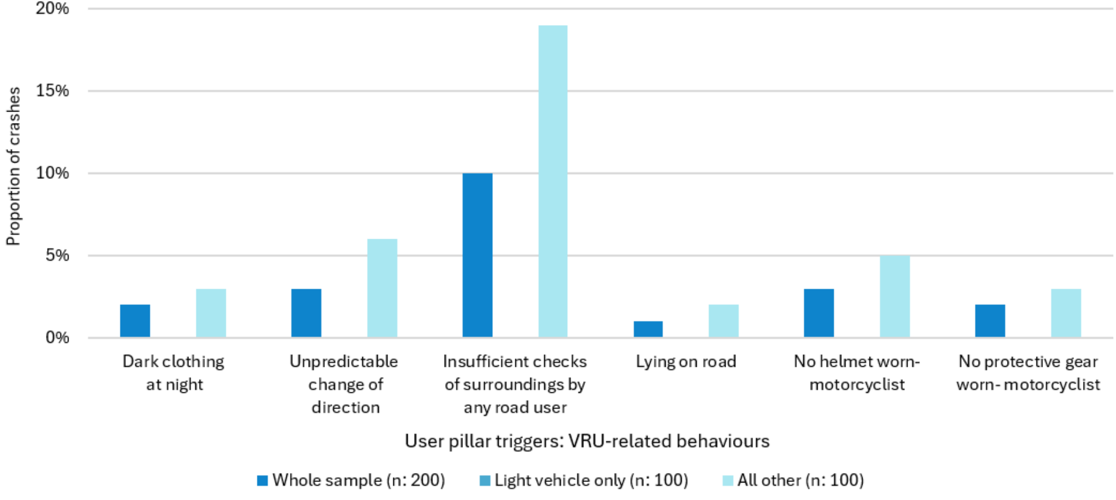



*Figure 28: User pillar triggers: VRU-related behaviours- proportion of crashes activating each trigger for the whole sample and by crash cohort.*

## 4.8. System failure vs illegal/reckless behaviour

**Highlights- System failure vs illegal/reckless behaviour**

- Most crashes involving ‘reckless/extreme’ or ‘illegal’ behaviour also exhibited multiple failures across the Safe System pillars.
- 52% of all fatal crashes involved ‘reckless/extreme behaviour’, 16% involved ‘illegal behaviour’, and 32% were attributed to everyday mistakes or system failures alone.

Building on the user pillar section above, this section will discuss the proportion of crashes attributed to everyday mistakes or ‘system failures alone’, ‘illegal behaviour’, and ‘reckless/extreme behaviour’. Key themes within each category are as follows:

- **‘Reckless/extreme behaviour’**: most cases involved multiple reckless triggers such as drugs and alcohol present, and no seatbelt worn, together in one crash. Fewer cases were attributed to extreme behaviours such as racing or reckless speeding.
- **‘Illegal behaviour’**: most cases (72%) involved illegal, or prescription drugs that affect driving, present in the system of a driver, combined with everyday mistakes such as losing control on a high-speed rural road.
- **‘System failure alone’**: everyday mistakes by road users (e.g. inadvertently drifting across the centreline due to being distracted by a passenger). Crashes involving VRUs and distracted drivers were also common.

Figure 29 displays the proportion of crashes by the classification groups above, for each cohort. In the whole sample, 52% of crashes involved ‘reckless/extreme behaviour’, 16% involved ‘illegal behaviours’, and 32% were attributed to everyday mistakes and system failures alone. The ‘light vehicle only’ cohort involved a greater proportion of ‘reckless/ extreme’ behaviours compared to the ‘all other’ crashes cohort, while the opposite is true for the proportion attributed to ‘system failures alone’.

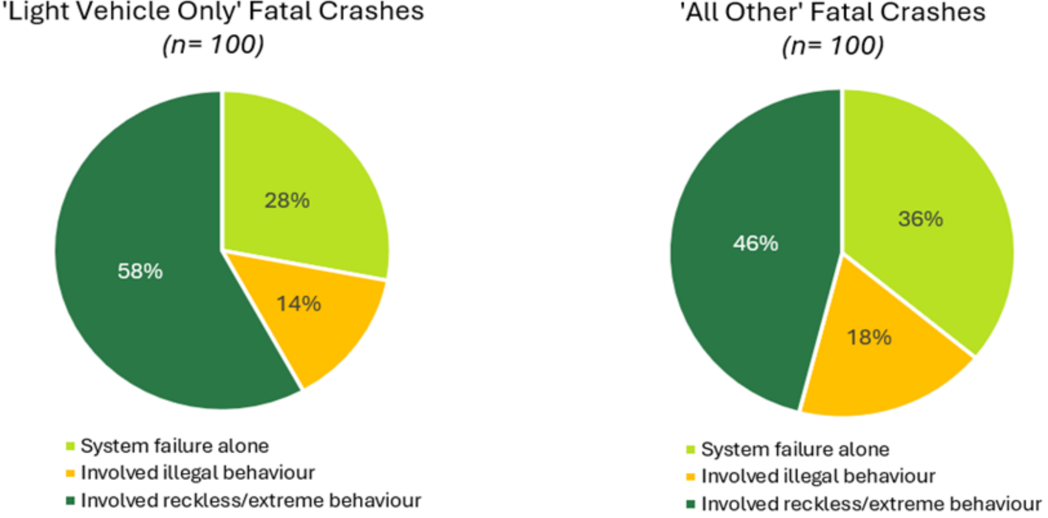



*Figure 29: System failures, illegal behaviours, and reckless/extreme behaviours in fatal crashes- in the ‘light vehicle only’ and ‘all other’ crashes cohort.*

Importantly, and as shown in Figure 30, most crashes involving ‘reckless/extreme’ or ‘illegal’ behaviour also exhibited multiple failures across the Safe System pillars. This suggests that crashes involving ‘reckless/extreme behaviour’ should not be viewed as road user problems alone. The wider system context needs to be considered for these crashes, as behaviours are almost always combining with other system failures to result in the fatality.

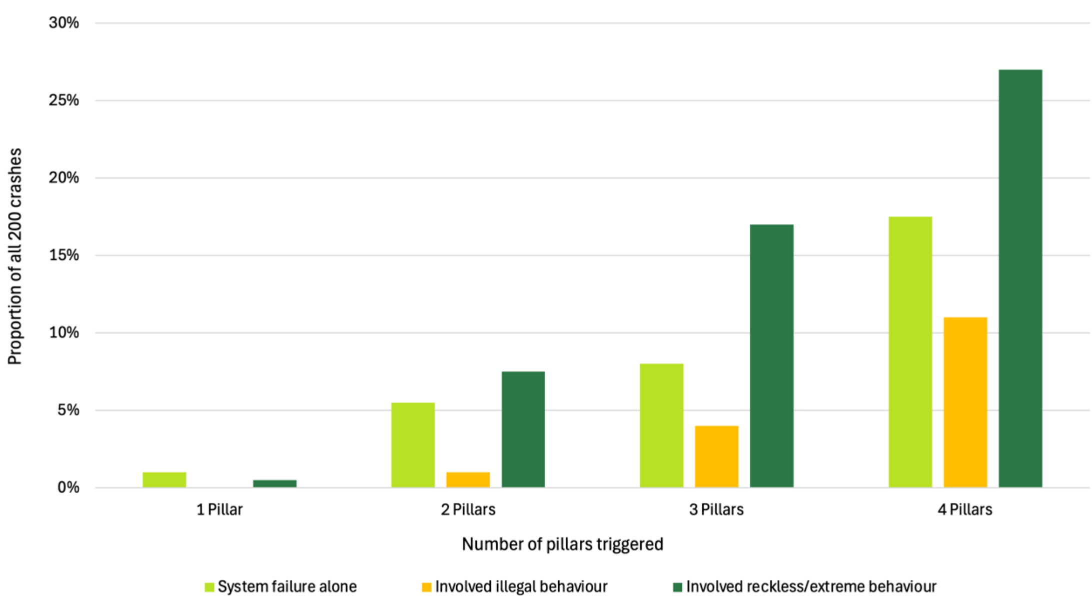



*Figure 30: Proportion of all crashes triggering multiple Safe System pillars by crash classification.*

To further explain this point, case studies of fatal crashes involving ‘reckless/extreme behaviour’ and ‘system failures alone’ will be compared.

> *A ute was driven on a winding 100 km/h rural road in the evening, lost control, ran off the road, and rolled into a paddock. The road lacked roadside barriers, had an operating speed significantly lower than the speed limit (62 km/h), and a high road infrastructure risk rating. The vehicle was reported as travelling at the speed limit, suggesting they were travelling too fast for the conditions. The ute was 20 years old lacking basic and relevant advanced vehicle features, was missing front airbags, and had a safety rating of two stars. The driver of the vehicle had a blood alcohol score over the legal limit, had illicit drugs present in their system, and was not wearing a seatbelt. In this crash, all four pillars were triggered, reflecting the total system failure which contributed to this crash, despite reckless user behaviour.*

> *A motorcyclist travelling straight on a 50 km/h urban connector road was struck by a right-turning car at a crossroad controlled by a give way sign in the early evening. There was no street lighting at the intersection reducing visibility between the users. The colliding car was 18 years old and had a VRU protection rating of three stars. The driver of the vehicle was an older driver, and failed to identify and give way to the motorcyclist. The motorcyclist was an inexperienced young rider on their learner license who attempted to brake in reaction to the car turning in front of them, however didn’t have sufficient time to come to a stop. In this crash all pillars were triggered, except for the speed pillar reflecting how multiple system failures came together to result in the fatality with no reckless behaviour involved.*

# 5. FINDINGS- CLUSTER ANALYSIS

A cluster analysis was carried out to better understand how system factors interact within individual crash contexts. The findings from the clusters, developed using hierarchical clustering on principle components approach, are summarised below. Additional details about the cluster analysis, including the validation exercise using the non-hierarchical k-means approach are provided in Appendix B: Cluster Analysis Further.

## 5.1. Cluster analysis overview

The analysis identified seven clusters of crashes as shown in Figure 31. A summary of the characteristics of each cluster is provided in Tables 3 & 4.

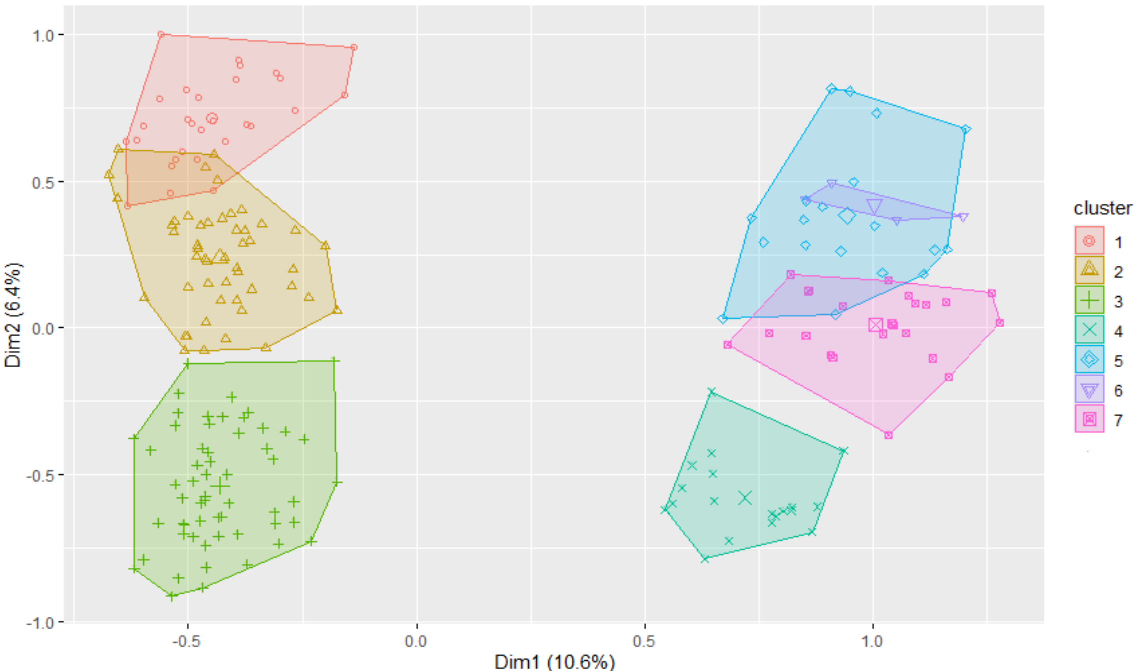



*Figure 31: Clusters developed through the Hierarchical Clustering method.*

Dimension 1 (x-axis of Figure 31) explains the most variance (10.6%) and primarily reflects patterns related to road-user and crash-type characteristics, capturing differences in vehicle type, mass mismatch, and crash configuration. Dimension 2 explains the second most variance (6.4%) and is driven by collision dynamics and impact-related factors. Together the two axis explains a moderate proportion of the total variation (17%) across the data. This level of explained variation is typical for MCAs with a moderate number of variables and many category levels, where inertia naturally disperses across dimensions.

The clusters tended to form distinct groups of crashes based primarily on the characteristics mentioned above, with other variables contributing to a lesser extent. However, some overlaps exist between the clusters when they had similar characteristics (e.g. the large/small vehicles and multiple light vehicles clusters where the crash impact is the same, but vehicle types differ). The two clusters containing pedestrian-and cycle-vehicle crashes were combined for discussion hereon as they have significant overlap.

## 5.2. Cluster descriptions

*Table 3: Cluster descriptions- clusters 1-3. Proportions use the total number of crashes in the cluster as the denominator.*

| | | 1. Large vs small vehicles<br>29 crashes | 2. Multiple light vehicles<br>49 crashes | 3. Single vehicle- run off road<br>57 crashes |
|---|---|---|---|---|
| **General** | Conditions | During daytime. Mostly fine weather and dry road conditions.<br>*83% daytime, 78% fine weather, 69% dry road conditions* | Half night, half day. Fine weather and dry road conditions.<br>*57% daytime, 80% fine weather, 71% dry road conditions* | Majority nighttime. Fine weather and dry road conditions.<br>*61% nighttime, 81% fine weather, 75% dry road conditions* |
| | Crash impact | Head on/side, unequal vehicle mass<br>*41% head on. 35% side impact* | Head on<br>*71% head on, 22% side impact* | Struck roadside object |
| **Vehicle Pillar** | Colliding vehicle type | Mostly trucks<br>*Truck (83%), bus (10%), ute (3%), car/wagon (3%)* | Over half large light vehicles<br>*Car/wagon (39%), SUV (31%), ute, (14%), truck (6%), bus (6%), van (4%)* | N/A |
| | Victim’s vehicle type | Mostly light vehicles<br>*Car/wagon (48%), SUV (17%), truck (14%), ute (7%), van (7%), bus (7%)* | Mostly cars<br>*Car/wagon (80%), SUV (16%), ute (2%), van (2%)* | Mostly light vehicles<br>*Car/wagon (60%), ute (18%), SUV (14%), van (7%), truck (2%)* |
| | Victim’s vehicle safety features | Half of the victim’s vehicles are lacking key safety features<br>*48% <= 3-star safety rating*<br>*45% missing ABS and/or ESC*<br>*55% missing relevant advanced safety features (e.g. lane keep assist)* | Most of the victim’s vehicles are lacking key safety features<br>*67% <= 3-star safety rating*<br>*55% missing ABS and/or ESC*<br>*80% missing relevant advanced safety features (e.g. lane keep assist)* | Most of the victim’s vehicles are lacking key safety features<br>*63% <= 3-star safety rating*<br>*58% missing ABS and/or ESC*<br>*74% missing relevant advanced safety features (e.g. lane keep assist)* |
| **Roads & Roadsides Pillar** | Land use/ crash location | Mostly rural, some motorway. Intersections overrepresented<br>*76% rural, 17% motorway, 7% urban*<br>*76% midblock, 20% intersection* | Rural roads, midblock<br>*78% rural, 12% motorway, 10% urban*<br>*76% midblock, 8% intersection* | Rural roads, midblock<br>*74% rural, 23% urban, 2% motorway, 2% designated beach*<br>*91% midblock, 9% intersection* |

| | | | | |
|---|---|---|---|---|
| | Relevant safety features | High-speed rural roads lacking centre barriers<br>*66% on >80km rural roads lacking relevant barriers, vehicle left the lane*<br>*10% obscured view/lacking continuity cues*<br>*4% on <=80km rural road lacking key safety features, vehicle left lane*<br>*20% features present/not relevant* | High-speed rural roads lacking centre barriers<br>*67% on >80km rural roads lacking relevant barriers, vehicle left the lane*<br>*8% obscured view/lacking continuity cues*<br>*4% on <=80km rural road lacking key safety features, vehicle left lane*<br>*21% features present/not relevant* | High-speed rural roads lacking roadside barriers<br>*60% on >80km rural roads lacking relevant barriers, vehicle left the lane*<br>*10% on <=80km rural road lacking key safety features, vehicle left lane*<br>*30% features present/not relevant* |
| **Speed Environment Pillar** | Mean operating speed posted speed limit ratio | Operating speed sometimes much lower than posted speed limit<br>*MOS >=10 km/hr lower than posted speed limit (31%)* | Operating speed sometimes much lower than posted speed limit<br>*MOS >=10 km/hr lower than posted speed limit (35%)* | Operating speed consistently much lower than posted speed limit<br>*MOS >=10 km/hr lower than posted speed limit (54%)* |
| **User Pillar** | At fault driver age | Mostly middle-aged drivers<br>*Middle aged- 25 to 74 (72%), young <25 (14%), older- 75+ (14%)* | Young drivers overrepresented<br>*Middle aged- 25 to 74 (61%), young <25 (35%), older- 75+ (4%)* | Young drivers overrepresented<br>*Middle aged- 25 to 74 (57%), young <25 (33%), older- 75+ (9%)* |
| | At fault driver license type | Mostly full licensed drivers, overseas drivers overrepresented<br>*Full (79%), overseas (14%), illegal (3%), developing driver (3%)* | Illegal and developing drivers overrepresented<br>*Full (51%), illegal (24%), developing driver (22%), overseas (2%)* | Developing drivers overrepresented<br>*Full (63%), developing driver (25%), illegal (9%), overseas (2%)* |
| | Driver fault/error | Distraction/inattention implicated frequently, some speeding<br>Distraction/inattention- 52%<br>Speed implicated- 31%<br>Intoxication present- 17%<br>Victim unrestrained- 7%<br>Extreme behaviour- 7% | Intoxication very common, speed, distraction/ inattention<br>Intoxication present- 69%<br>Speed implicated- 45%<br>Distraction/inattention- 39%<br>Extreme behaviour- 18%<br>Victim unrestrained- 10% | Intoxication very common, speed implicated, no seatbelt.<br>Intoxication present- 61%<br>Victim unrestrained- 54%<br>Speed implicated- 54%<br>Distraction/inattention- 28%<br>Extreme behaviour- 14% |
| **Crash classification** | | Mostly system failures alone<br>*69% system failure alone*<br>*17% illegal behaviour*<br>*14% reckless/extreme behaviour* | Mostly reckless/illegal behaviour<br>*47% reckless/extreme behaviour*<br>*27% illegal behaviour*<br>*26% system failure alone* | Consistently reckless behaviour<br>*58% reckless/extreme behaviour*<br>*26% system failure alone*<br>*16% illegal behaviour* |

*Table 4: Cluster descriptions- clusters 4-7. Proportions use the total number of crashes in the cluster as the denominator.*

| | | **4. Motorcycle- run off road 19 crashes** | **5/6. Vehicle vs pedestrian/cyclist 23 crashes** | **7. Vehicle vs motorcycle 23 crashes** |
|---|---|---|---|---|
| **General** | Conditions | Mostly during daytime. Fine weather and dry road conditions.<br>*63% daytime, 100% fine weather, 100% dry road conditions* | Half night, half day. Fine weather and dry road conditions.<br>*57% daytime, 78% fine weather, 83% dry road conditions* | Half night, half day. Fine weather and dry road conditions.<br>*57 % daytime, 96% fine weather, 96% dry road conditions* |
| | Crash impact | Struck roadside object<br>*100% struck roadside object* | Struck pedestrian/cyclist<br>*83% struck pedestrian, 17% struck cyclist* | Struck motorcyclist/moped |
| **Vehicle Pillar** | Colliding vehicle type | N/A | Mostly car/wagon<br>*Car/wagon (61%), SUV (13%), ute, (13%), truck (9%), van (4%)* | Mostly car/wagon<br>*Car/wagon (61%), SUV (26%), ute, (17%), motorcycle (4%)* |
| | Victim's vehicle type | Motorbikes | N/A | Motorbikes |
| **Roads & Roadsides Pillar** | Land use/ crash location | Mostly rural, some urban roads. Midblock locations.<br>*57% rural, 37% urban, 5% motorway*<br>*84% midblock, 16% intersection* | Urban arterial roads. Intersections and driveways overrepresented<br>*78% urban, 22% rural*<br>*43% midblock, 40% intersection, 17% driveway* | Urban and rural roads, mostly intersections<br>*57% urban, 43% rural*<br>*57% intersection, 43% midblock* |
| | Relevant safety features | High-speed rural roads<br>*42% on >80km rural roads lacking relevant barriers, vehicle left the lane*<br>*11% on <=80km rural road lacking key safety features, vehicle left lane*<br>*47% features present/not relevant* | Lacking pedestrian facilities<br>*35% lacking crossing facility or best practice safety features*<br>*17% rural roads, no footpath*<br>*9% no cycling facility*<br>*4% lacking roadside barriers*<br>*35% safety facilities present* | Range of relevant safety features<br>*39% standard urban intersection*<br>*26% on >80km rural roads lacking relevant barriers, vehicle left the lane*<br>*9% on <=80km rural road lacking key safety features, vehicle left lane*<br>*26% features present/not relevant* |

| **Speed Environment Pillar** | Mean operating speed posted speed limit ratio | Operating speed consistently much lower than posted speed limit<br>*MOS >=10 km/hr lower than posted speed limit (58%)* | Operating speed similar to posted speed limit<br>*MOS >=10 km/hr lower than posted speed limit (26%)* | Operating speed similar to posted speed limit<br>*MOS >=10 km/hr lower than posted speed limit (26%)* |
|---|---|---|---|---|
| **User Pillar** | At fault driver age | Middle aged riders<br>*Middle aged- 25 to 74 (74%), young <25 (26%),* | Middle aged drivers<br>*Middle aged- 25 to 74 (82%), young <25 (17%)* | Representative mix of ages<br>*Middle aged- 25 to 74 (60%), older- 75+ (17%), young <25 (22%)* |
| | At fault driver license type | Inexperienced riders, illegal license overrepresented<br>*Developing rider (42%), full (37%), illegal (21%)* | Mostly full licensed drivers<br>*Full (65%), developing driver (17%), illegal (13%), overseas (4%)* | Illegal and inexperienced riders/ drivers<br>*Illegal (43%), developing driver (35%), full (22%)* |
| | Driver fault/error | Speed and intoxication common, extreme behaviour overrepresented<br>Speed implicated- 63%<br>Intoxication present- 58%<br>Extreme behaviour- 21%<br>Distraction/inattention- 20% | Distraction/inattention, some speed and intoxication<br>Distraction/inattention- 74%<br>Speed implicated- 43%<br>Intoxication present- 35%<br>Extreme behaviour- 17% | Intoxication and distraction/ inattention common, speed and extreme behaviour often implicated<br>Intoxication present- 61%<br>Distraction/inattention- 52%<br>Speed implicated- 39%<br>Extreme behaviour- 35% |
| **Crash classification** | | Mostly reckless/illegal behaviour<br>*42% reckless/extreme behaviour*<br>*32% illegal behaviour*<br>*26% system failure alone* | Mostly system failures alone<br>*57% system failure alone*<br>*35% reckless/extreme behaviour*<br>*9% illegal behaviour* | Mostly reckless/illegal behaviour<br>*52% reckless/extreme behaviour*<br>*30% illegal behaviour*<br>*17% system failure alone* |

## 5.3. Cluster profiles

**Cluster 1: Large vs small vehicles**

Cluster 1 (15% of all crashes) is defined by high-mass vehicles colliding with lighter vehicles, typically head-on impacts, mid-block on high-speed rural roads lacking centre barriers, but also at intersections. Mostly involving middle aged full licensed drivers, with overseas drivers overrepresented. Often involving distraction/ inattention and/or speed, with most crashes resulting from everyday mistakes and system failures alone.

**Cluster 2: Multiple light vehicles**

Cluster 2 (25% of all crashes) consists of crashes between two light vehicles, mostly head-on impacts which largely took place at mid-block locations on high-speed rural roads without centre barriers. Young drivers were overrepresented, as were those driving illegally based on license, and developing drivers. Intoxication featured prominently alongside speeding and distraction, with the profile strongly shaped by reckless or illegal behaviour.

**Cluster 3: Single vehicle- run off road**

Cluster 3 (28% of all crashes) is characterised by crashes where light vehicles lost control on high-speed rural roads, which often lacked roadside barriers, and struck roadside objects. The MOS on the crash road was consistently much lower than the speed limit, suggesting mixed instructional cues. The majority of crashes occurred at night, with young and developing drivers overrepresented. Intoxication, speeding, distraction, and the absence of seatbelt use feature notably, with reckless/extreme behaviour implicated in over half of these crashes.

**Cluster 4: Motorcycle- run off road**

Cluster 4 (10% of all crashes) is defined by crashes where motorcyclists left the road mid-block at rural and urban locations and collided with roadside objects. The MOS on the crash road was often significantly lower than the speed limit, suggesting mixed instructional cues. Most were middle-aged, with inexperienced riders notably overrepresented. Speed and intoxication were frequent contributors, and reckless/illegal behaviour was more common than everyday mistakes and system failures alone.

**Cluster 5/6: Vehicle struck pedestrian/cyclist**

This cluster (11% of all crashes) involves vehicles striking pedestrians and cyclists, predominantly on urban arterial roads at intersections, or driveways. Infrastructure such as such as safe crossings, footpaths, and cycling infrastructure were often missing. Drivers of the colliding vehicle were mostly middle-aged and fully licensed. Distraction/ inattention was the dominant contributing factor, with speeding and intoxication present in fewer cases. The majority of cases were attributed to everyday mistakes and system failures alone.

**Cluster 7: Vehicle struck motorcycle**

Cluster 7 (11% of all crashes) is characterised by crashes involving light vehicles striking motorcyclists, most often at intersections, on both urban and rural roads. Riders and drivers who were inexperienced and held illegal licenses were mostly involved. Intoxication and distraction/inattention were frequent contributing factors, with speeding and extreme behaviour also commonly implicated. Most involved reckless/illegal behaviour.

# 6. DISCUSSION & IMPLICATIONS FOR POLICY AND PRACTICE

## 6.1. Discussion of key findings

*Multiple system failures*

This research reaffirms our understanding that multiple system factors combine to result in fatal crashes. Analysis showed that 99% of all crashes analysed involved multiple system failures across Safe System pillars, and 56% of crashes had failures in all four pillars. This suggests that as well as paying attention to all parts of the Safe System, interactions between system components in potential crashes are also important.

*Road design and speed*

There was a clear interplay between road features and speed in the research, with a lack of protective features and unsurvivable speeds often coming together to result in a fatal crash. This was highlighted on 100 km/h rural roads without centre-median or roadside barriers, where 51% of all crashes, and 62% of 'light vehicle only' crashes occurred. Similarly, most pedestrian/cyclist crashes occurred on urban connector and rural roads, with 50 or 100 km/h speed limits, that lacked adequate infrastructure to separate road users. To meaningfully reduce road fatalities in New Zealand, apart from reducing vehicle kilometres travelled, the research suggests that efforts must focus on either reducing posted limits to survivable speeds or installing protective features to separate road users on roads with above survivable speed limits. Consistent application of safe speeds or infrastructure across the country, in a coherent way, is also important. As well as contributing to continued fatalities, this incoherence also leads to a confusing road network, making it harder for motorists to behave safely. For example, a road with a speed limit of 100 km/h might have very similar characteristics to one with a posted limit of 80 km/h, sending inconsistent signals to motorists leading to inconsistent behaviour and higher risk.

The research suggests frequent mixed messages about the speed that is appropriate or safe for the road suggesting a greater need to match speed limits to the look and feel of the road, as well as risk. This was highlighted by the fact that 45% of fatal crashes occurred on roads where the operating speed was significantly lower than the speed limit. In such circumstances (e.g. a winding road with 100 km/h speed limit), it may encourage motorists to travel too fast for the conditions, being influenced by a higher speed limit. A greater focus on consistent cues for motorists in terms of road categories, road design, and speed limit, would likely be helpful in influencing safe and appropriate speeds.

Having large vehicles such as trucks and light vehicles travelling together on unprotected high-speed rural roads contributes substantially to the cluster of unequal vehicle masses in fatal crashes (29 crashes). Efforts are needed to provide centre-median barriers on such roads that are main trucking routes, to prevent head-on crashes with light vehicles at high speeds.

### *Vehicles*

Vehicles driven by the victim of the fatal crash were always lighter or of equal weight to the colliding vehicle, on average older than the NZ light vehicle fleet, often had low safety ratings, and were missing basic (ABS or ESC) and advanced safety features. Most (70%) vehicles involved in fatal collisions with VRUs also had poor VRU protection safety ratings.

These findings suggest that the continued promotion and incentivisation of vehicle safety features, through newer cars, is important for all road users. Individuals may also (rightly) see a larger vehicle as being safer for themselves without understanding the risk of larger vehicles to other road users. However, taking a more collective view, education and incentives for smaller vehicles may be worth considering, as they are often more environmentally friendly, cheaper to run, and safer for VRUs. For example, with the introduction of road user charges (RUCs) for all vehicles, it may be possible to set RUCs to incentivise safer vehicle choices by reflecting the range of externalities associated with vehicles including crash risk to occupants and others, impacts on the environment, running costs, and even road space taken up by the vehicle.

The mass difference between vehicles on New Zealand roads facilitated by the importation of older used vehicles alongside the continued increase in size and mass of new passenger vehicles directly contributes to road safety risk. This suggests that alongside education and incentives to promote safer vehicle use, regulatory changes are required to phase out or limit the importing of old vehicles lacking key safety features (basic and more advanced e.g. lane keep assist).

### *Road users*

Victims of road crashes continue to be skewed towards younger road users, and males were far more frequently implicated as both the victim and driver of the colliding vehicle than females. Almost a third of fatal crashes involved a road user in breach of their license conditions or without a license to operate the vehicle, and half of learner/restricted drivers involved in crashes were in breach of conditions. Motorcyclists without a class 6 (motorcycle) license were also common. Continuing to strengthen licensing in line with best practice (e.g. supervised practiced, minimum stage times, and ensuring penalties are aligned to risk), while considering equity concerns such as access to licensing by those with lower socio-economic backgrounds are likely to be important.

40% of crashes involved distraction or inattention from a road user involved, acknowledging there can be significant under-reporting of inattention, particularly from fatigue. Distraction and insufficient checks were particularly prevalent in crashes involving VRUs suggesting that intuitive, user-friendly, and safe road environments, particularly to protect VRUs, are important as the shift towards multimodal urban transport continues. This should be supported by increased detection, education, and enforcement related to inattention mechanisms such as mobile phone use, with a stronger expectation by motorists that such behaviour will have consequences.

In 34% of 'light vehicle only' crashes, the victim was not wearing a seatbelt, consistent with earlier findings [6,12]. This was often associated with the presence of drugs or alcohol over the legal limit in the drivers' system. Further effort is needed to understand and address the circumstances and motivations where seatbelts are not being worn. Given the seatbelt wearing rate of the motoring public is approximately 98% [32], there is

a significant opportunity to reduce fatalities through increased seatbelt use. Hirsch et al. (2017) developed profiles of typical situations when people don't wear seatbelts, and recommended that a deeper dive to understand the system factors and associated solutions for the range of people not wearing seatbelts is needed.

Almost half (47%) of all crashes involved a road user travelling too fast for the conditions, or speeding by greater than 10 km/h. Of the crashes involving speeding, two thirds involved speeding at least 20 km/h over the posted speed limit. This is interesting as it suggests that extreme speeding is implicated more frequently in fatal crashes as opposed to the normal distribution of speed, whereby most speeding involves travelling slightly over the speed limit. Because speeding of this nature is certain to be deliberate, continued or expanded speed enforcement with appropriate corresponding fines or penalties is needed. However, it is also acknowledged, as outlined earlier, that many speed limits don't accurately reflect the safe operating speed for a road.

Over half (57%) of fatal crashes involved a road user with alcohol over the legal limit (20%), and/or illegal or pharmaceutical drugs that affect driving (42%) present in the drivers' system. The proportion of crashes involving alcohol is lower compared with earlier research (discussed later), while the presence of drugs wasn't considered in past work due to data unavailability. However, recently the presence of drugs in road crashes has begun to be routinely reported in TCRs and has also been retrospectively added to historical fatal crash reports. With this updated data, a stark trend emerges of rapidly increasing drug involvement, but encouragingly reduced alcohol involvement in fatal crashes over time (Figure 32).

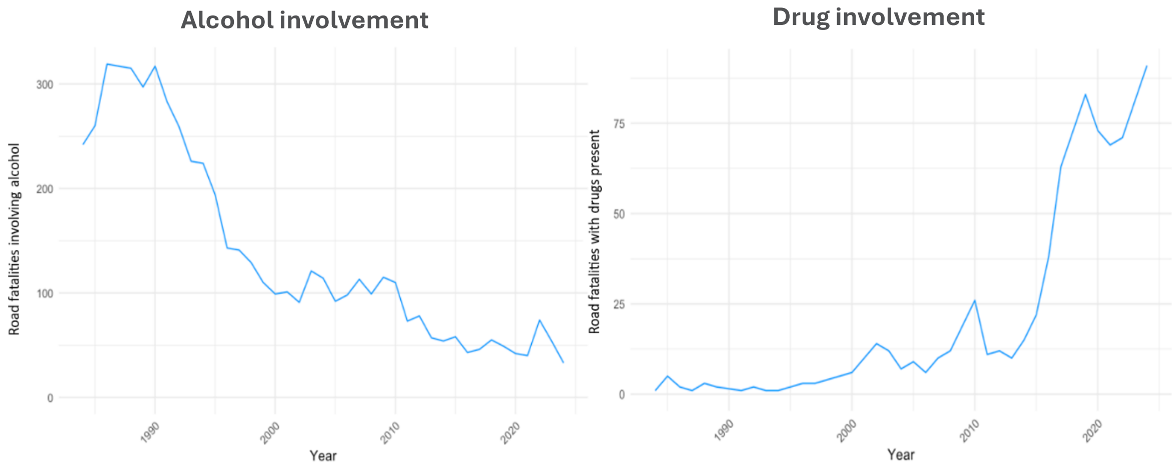



*Figure 32: New Zealand road fatalities involving alcohol (left graph) and drugs (right graph) between 1984 to 2024. From Ministry of Transport (2025) [37]. Note that alcohol is identified when a driver's blood/breath alcohol level is above the legal limit. Drugs are identified when present in the driver's blood. 'Officer suspicion' was previously used as a means of assigning alcohol/drugs to the crash, but from 2016, this was removed. Also, drug testing for fatal crashes was not regularly carried out before approximately 2019.*

This trend is in line with broader societal trends in New Zealand which suggest that illicit drug use is rising, with wastewater testing showing significant recent increases in methamphetamine and cocaine use [33]. The 2023/24 NZ Drug survey also reports widespread use of cannabis (15.6%) and MDMA (4.8%) amongst the adult population (over 15 years old) in the past year [34]. In contrast, at a societal level, alcohol use is decreasing, particularly among younger adults, but remains widespread [35].

It is clear that a significant proportion of fatalities are associated with drug use, and a better understanding of the impairment effect of drug presence is needed, along with policy settings to limit or mitigate drug use while driving. The implementation of roadside drug testing and related enforcement activities may also play a role in countering this concerning trend [36].

*System failures alone vs illegal/reckless and extreme behaviours*

Overall, 52% of all fatal crashes involved ‘reckless/extreme behaviour’, 16% involved illegal behaviours, and 32% were attributed to everyday mistakes and ‘system failures’ alone. Most crashes involving ‘reckless/extreme’ or ‘illegal’ behaviour also exhibited multiple failures across the Safe System pillars. Several common user behaviours tended to cluster together in reckless crashes (e.g. alcohol/drug use and seatbelt non-use), but also often clustered with system factors such as a lack of run off road protection.

Together this suggests that a proportion of road users are either operating recklessly or outside of legal operating conditions. Education and enforcement efforts are needed to support more compliant road user behaviour. Enforcement, particularly on rural roads is supported by this research. Evidence-based education or other intervention around the dangers of intoxication, speed, and other high-risk behaviours is also required.

Regardless of road user crash influences, the research has shown that other system failures are typically interacting to result in fatal crashes. As outlined earlier, this indicates that actions to improve the safety of the speed and road environments, along with safer vehicles, are required to help mitigate crashes even if they involve reckless or illegal behaviour. Additionally, actions outside of the road safety space may be required to address reckless and extreme behaviours, which are often linked to wider societal issues (e.g. risk-taking behaviours, socio-economic deprivation, addiction, etc.).

## 6.2. Comparison with other literature

This study was designed to allow comparisons with other similar studies, particularly the fatal crash cohort in Mackie et al. (2017). These comparisons enable an analysis of trends in New Zealand light vehicle crashes over time. Other previous Safe System analyses conducted in New Zealand were also drawn upon to compare findings related to crashes involving those driving for work and pedestrians [5,7]. In South Australia, Wundersitz & Raftery (2025) carried out an analysis of fatal and injury crashes that built on their earlier work. Although, the South Australian group used more comprehensive datasets including coroners’ reports and in-depth crash investigations, relevant Australia/ New Zealand comparisons are possible, and have been undertaken here, with the limitations noted.

### 6.2.1. Comparison with Mackie et al. (2017)

*Comparing the contributing factors to ‘light vehicle only’ crashes*

Overall, results from the ‘light vehicle only’ cohort in this study are very similar to those of Mackie et al. (2017). We suggest that this is because despite some changes in societal and policy conditions and some aspects of the Safe System (e.g. safer vehicles), there haven’t been many substantial differences across the nation-wide road transport system

in the period between the studies. Many of the changes that have occurred have not had widespread national adoption, possibly due to changing policy settings over this period. Therefore, we wouldn't expect much to change. A range of error types remain in fatal crashes ranging from deliberate reckless/illegal behaviours through to everyday mistakes.

One notable difference was the number of pillars implicated in a crash. The proportion of crashes triggering all four pillars is higher in this study (67% vs 56% in Mackie et al., 2017), likely due to the methodological difference mentioned below. In terms of individual contributing factors, those in the roads and roadsides and speed pillars were very similar, and most crashes occurred on high-speed rural roads with a lack of adequate protection.

A key methodological difference between the earlier study and this study was the new factor for absent advanced collision avoidance features, in line with vehicle technology developments. This is a key reason why the vehicle pillar was triggered more often in the present study (91.0% vs 79.5%). Other notable vehicle pillar comparisons were:

- The proportion of crashes where the victim's vehicle was greater or equal to 14 years old was higher in this study (70%) compared to Mackie et al (2017) (59%).
- Vehicles without airbags dropped significantly (31-81% depending on the type of airbag in the previous research), to 15% in this study, as would be expected.
- Vehicles missing basic crash avoidance features also dropped substantially from 81% missing ESC and 28% missing ABS in the previous study to 57% of vehicles missing either feature in this study.

Overall, this suggests that vehicles lacking basic vehicle safety features have reduced over time. However, the expected safety standard of vehicles has also increased, particularly with the advent of advanced safety features such as lane keep assist.

Some differences were also observed in user behaviours between the two studies. Note that the current study considered a much wider range of user behaviours and so not all factors are comparable to the previous work. Key differences are listed below:

- The proportion of crashes with alcohol implicated reduced from 32% previously to 20% in the current research. However, a different metric, "alcohol suspected" was used previously, while this study used proven intoxication with alcohol. Nevertheless, routinely collected data supports this reduction, also showing reduced crashes related to drink driving between 2015/16 and 2024 [37].
- Vehicles travelling too fast for the conditions was lower in the present study (40%) than previously (55%). However, in a substantial proportion of cases, the TCR listed that it was 'unknown' whether the vehicle was travelling too fast for the conditions. Therefore, this difference may be insignificant.
- Speeding by more than 10 km/h was implicated in a greater proportion of crashes in this study (28%) than Mackie et al (2017) (21%).

*Comparison of the nature of 'light vehicle only' crashes over time*

Figure 33 compares the proportion of fatal crashes attributed to 'reckless/extreme behaviours' and 'system failures alone' between the two studies. To compare the findings of the two studies, the proportion of crashes in the 'illegal behaviour' category from the

current study was merged with that of ‘system failures alone’. This aligns with the crash classifications of Mackie et al. (2017) as ‘illegal behaviour’ crashes would not have met the threshold to be described as ‘reckless behaviour’.

The proportion of light vehicle only crashes with ‘reckless/extreme’ behaviour is higher in the current study. We suggest the main reason for this is the addition of drugs, combined with other reckless contributors in the present study. The presence of drugs was not reported in TCRs at the time of the previous study.

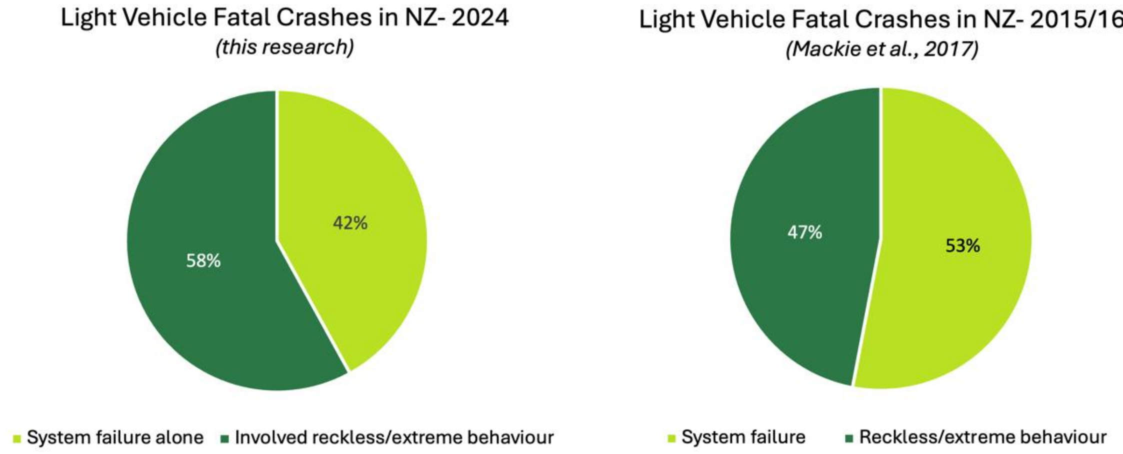



*Figure 33: Study data vs data from Serious Injury Crashes study (Mackie et al., 2017) – System failures and reckless/extreme behaviours in fatal light vehicle crashes.*

Apart from increased speeding and decreased alcohol involvement in the present study, there was no meaningful change in the reckless contributors or triggers between studies.

To allow a fair comparison between the two studies, we removed the ‘drugs present’ category from the present study and reassessed the proportion of crashes involving ‘reckless/extreme behaviour’ (Figure 34). With this adjustment made, the proportion of crashes involving reckless/extreme behaviour is similar between the studies. The findings do mean that the increased involvement of drugs may be from increased reporting of drugs in road crashes or from increasing drug use as suggested by other data sources. The study cannot definitively say which is true.

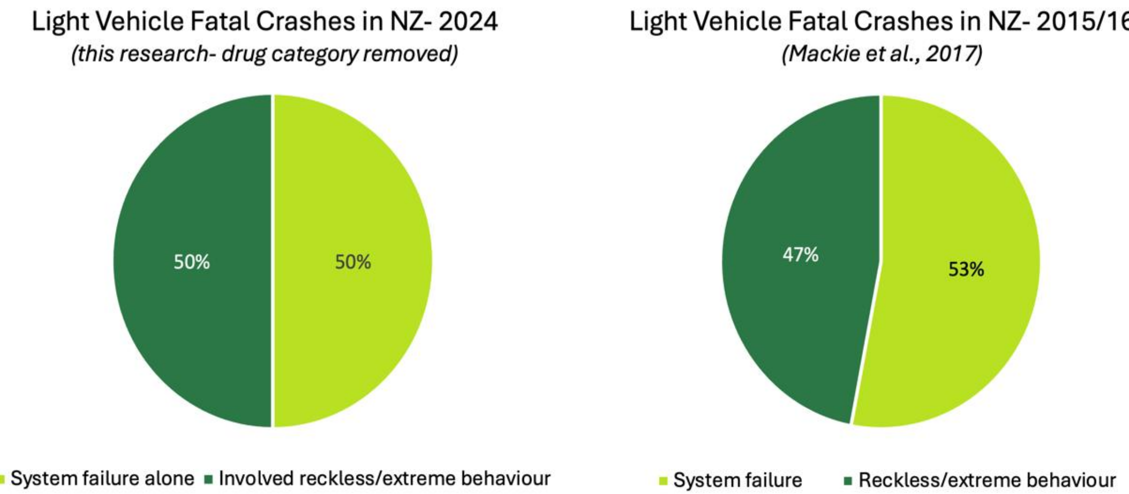



*Figure 34: Study data vs data from Serious Injury Crashes study (Mackie et al., 2017)- System failures and reckless/extreme behaviours in fatal light vehicle crashes, drug category removed.*

### 6.2.2. Comparison with other New Zealand literature

Raja et al. (2023) conducted a Safe System analysis of driving for work (DFW) crashes [7]. They found that crashes involving road users who were DFW were less likely to involve reckless behaviour when comparing to the comparator study described in the previous section (Mackie et al., 2017). This finding is reinforced by the present research which found that crashes involving trucks were less likely to involve reckless behaviour.

Hirsch et al. (2021) conducted a similar analysis for pedestrian crashes [5]. Insufficient pedestrian infrastructure was implicated in a greater proportion of crashes in this study (63% vs 28% of cases). However, the criteria for this trigger were slightly different in that Hirsch et al used the total lack of infrastructure, whereas this study used lack of best practice infrastructure. Interestingly, no crashes in this study involved a pedestrian being struck on a priority crossing, compared to 12% in Hirsch et al. This could be due to wider use of raised pedestrian crossings in recent years. Other key findings such as the frequent implication of inattention/ distraction and colliding vehicles with high masses/bonnet shapes in fatal pedestrian crashes were similar between studies.

### 6.2.3. Comparison with Wundersitz & Raftery (2025)

The present research using all 200 crashes can also be compared with previous South Australian research [8,9]. Alongside the differences in the comprehensiveness of datasets mentioned earlier, there were also some other methodological differences which affect whether a crash was deemed to have reckless/extreme behaviour. Wundersitz & Raftery set higher thresholds for some contributors, for example, in their study vehicles had to be travelling at 50% over the speed limit to be considered reckless/extreme, while the present study used a blanket value of >=20 km/h over the posted speed limit. Wundersitz & Raftery also didn’t consider impairment from pharmaceutical drugs that affect driving.

It’s also worth noting that the fatal crashes analysed in the most recent South Australian study were from 2014/15, approximately 10 years prior to the crashes in the present study. Therefore, trends may differ by time period as well as between locations.

Figure 35 shows that the proportion of crashes attributed to ‘reckless/extreme behaviour’ is significantly higher in the present study compared with the recent South Australian study, with the opposite true for ‘system failures alone’, and ‘illegal behaviours’.

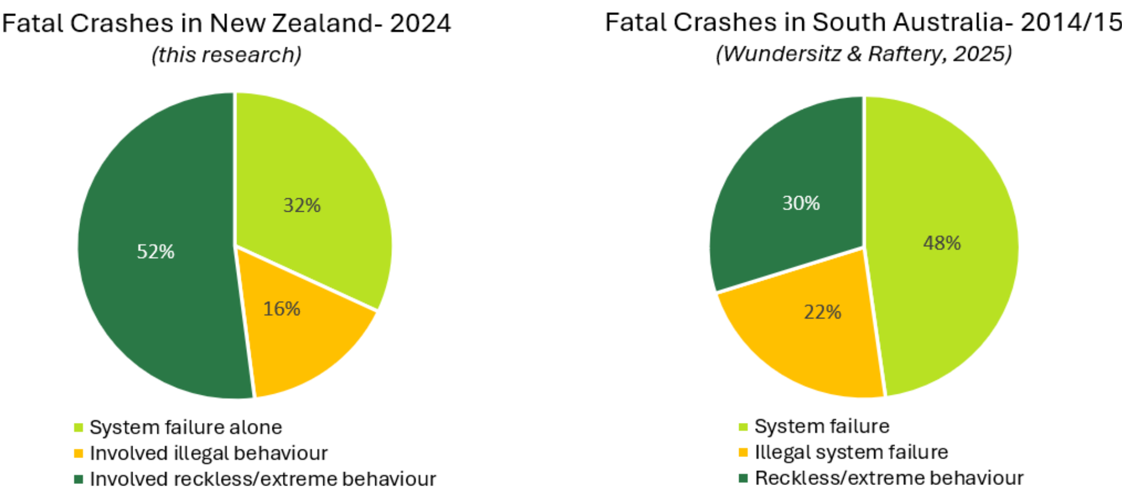



*Figure 35: Study data vs data from South Australian study (Wundersitz & Raftery, 2025)- System failures, illegal system failures, and reckless/extreme behaviours in fatal crashes.*

A key factor driving this difference is the number of crashes involving illicit drugs, which was significantly higher in our study (32% vs 23% in Wundersitz & Raftery, 2025). Further to this, Wundersitz and Raftery (2025) didn't consider driving with legal pharmaceutical drugs that affect driving (present in 11% of crashes in this study). This contributes further to the greater proportion of crashes involving reckless/illegal behaviours in our work.

Interestingly, Wundersitz and Raftery also found a decrease in alcohol crashes and an increase in crashes involving illicit drugs when comparing to an earlier study that analysed crashes from 2008/09 calendar year. This, and other research and data, reinforce our findings suggesting that alcohol use is decreasing but being replaced by drug use in road crashes and wider society [8,20,33–35,37,38].

Overall, the results may suggest a divergence in the nature of fatal crashes between New Zealand and Australia. Crashes in South Australia may be trending towards 'system failures alone', whereas New Zealand trends have remained approximately static (as per comparison with Mackie et al., 2017). It could be that conditions are changing in NZ that aren't happening in South Australia, or alternatively more recent data from Australia may show trends like those seen in New Zealand. However, the results in Wundersitz and Raftery (2025) were not broken down for other reckless/extreme behaviour triggers, so it is challenging to determine other factors which could be contributing to the differences between the two studies.

The overarching point made by both studies is that while reckless or illegal behaviour is often present in fatal crashes, many crashes result from everyday mistakes. Even crashes that involve reckless/extreme or illegal behaviours almost always involve system failures.

## 6.3. Study and data limitations

As stated earlier, analysis for studies of this type is limited by the information available in TCR reports and associated speed management and vehicle safety databases, and their changes over time (e.g. practices in recording drug use). The research does not provide a depth of understanding of individual crashes that might be achieved from serious crash or coroners' investigations, but rather a Safe System view of a cohort of crashes large enough to draw themes and clusters of crash types. For most crash cases, the information available provided a reasonable understanding of the system pillars that were likely to have played a part in the crash. The uncertainty was more related to the extent to which each pillar was critical in the crash.

TCRs are generally completed at the scene of the crash (or shortly after) by the attending police officer. The accuracy and level of detail included in TCRs is variable and often relies on driver and witness statements, particularly for speed estimates and driver behaviours at the time of the crash. As noted in previous research, TCRs for fatal crashes also tend to have less detail, such as lacking driver/witness statements, few comments on possible causes, and frequent references to the SCU report (to which we did not have access) for more detail [5,11]. It's worth noting that where the level of detail was insufficient to 'reasonably' interpret the contributing factors, the case was excluded. As has been mentioned in similar studies, a system for more ready access to the range of data sources related to crashes (SCU and coroners' reports, council records, ACC data, hospitalisation data) would be helpful for in-depth studies of crash situations.

The extent to which system contributors were key to the crash and fatality, as opposed to simply associations, is difficult to deduce from the present research for the reasons mentioned above. Even still, caution would be needed when attempting to include or exclude factors key to the fatality, as system contributions can be complex and difficult to accurately capture with crash records. However, previous more in-depth analyses of crash cases using SCU reports have attempted this [39], and a larger-scale study could give greater certainty to key system factors that were crucial to a crash or fatality.

A key issue that is difficult for road policing, as well as this research, is the extent to which drugs cause impairment if they are detected through testing. Further research is needed to demonstrate the link between different concentrations of various drugs and impairment, acknowledging the difficulty of establishing this link for any circumstance.

With regard to the cluster analysis, the internal validity of the identified clusters was assessed by comparing the clusters formed by two methods, HCPC and k-means approaches. However, we were unable to assess the external validity of those clusters, i.e. the extent to which the clustering results can be generalised to other crash events. Additional data for external validity checks was not available.

Another limitation is the Safe System focus and lack of wider sociotechnical considerations, which was determined by the scope of this research. A sociotechnical approach goes beyond what happened at the moment of the crash and asks why the crash or fatality happened, looking at upstream considerations that sets the scene for fatal crashes. For example, there may have been a mismatch between the speed limit, the speed of the crash, and the road context, and this may have been because speed limit setting and the road characteristics were not well coordinated in policy, investment programmes, or local practices. Earlier research focussing on work-related crashes demonstrated how this might be applied [7].

An important limitation is a focus on fatal crashes only and not including serious crashes in line with normal Safe System practice. This means that the results are likely to focus more on high-speed vehicle crashes on rural roads, than lower speed urban crashes involving a wider range of road users. Also, the focus on fatal crashes implies more crashes involve reckless/extreme and illegal behaviour than in serious injury crashes, which tend to involve everyday mistakes and system failures, as seen in previous research. This was discussed at the beginning of the report and so isn’t covered any further here, apart from reinforcement of a key implication which is the need for a ‘very serious crashes’ category to help make analyses such as these more meaningful.

## 6.4. Implications for policy and practice

This research reminds us that fatal crashes occur when multiple system failures come together. It reinforces that to significantly reduce the most severe crashes, all aspects of the Safe System must be addressed, and research findings should be utilised to develop policies and practices that are evidence-based. Other important factors, often not considered within the Safe System arena, include broader societal issues such as vehicle dependence and how this flows through to exposure to road risk.

Increased reckless or illegal behaviour is a possible trend, but so is the changing nature of these behaviours in fatal crashes (e.g. particularly the presence of drugs). The trend of

reduced alcohol involvement in fatal crashes is promising, likely linked to road policing efforts and societal trends of less drinking, particularly among younger adults. Attention should be given to better understanding these behaviours, as well as the trends that drive them, and developing actions accordingly. To do this, a wider view of the societal issues that intersect with road safety should be taken (e.g. why might drug use be increasing and why does this spill into road use?).

The research reinforces the point that many everyday road users make mistakes which can inadvertently lead to severe consequences. However, the need for a more nuanced understanding of the road user contribution to the Safe System is also suggested by the research, including situations where road users wilfully act recklessly. In the Dutch road safety strategy – Advancing Sustainable Safety [40], state awareness by the road user was added as a fifth principle in addition to road design principles. This was done in acknowledgement that sometimes road users deliberately break rules and safe driving conditions. This is a delicate matter as the Safe System paradigm tends to accept human variability (after years of blaming road users), and focus more on engineering matters such as road design, speed, and vehicles. However, a more sophisticated view of the Safe System might seek to gain a more detailed understanding of road user circumstances, and the interventions that are likely to make a difference to reduce reckless/extreme behaviours, in addition to the system factors that will mitigate everyday mistakes.

The research also highlighted many situations where road infrastructure, or speed limit shortcomings, have contributed to road users losing their lives in a range of settings. A strong road safety infrastructure programme is needed, allowing innovative and lower-cost countermeasures to be adopted, based on more recent practices (such as 2-1 roads and Intersection Speed Zones), so that consistency at a national scale can be achieved. Likewise, speed limits that are better matched to various road types, protective features, and risk, are needed.

The vehicle contribution to fatalities is also clear from the research. Greater clarity about vehicle safety issues and associated education, incentives, and changes to regulatory settings are needed, including a focus on vehicle age and safety features, mismatch between vehicle mass in collisions (and the road designs that allow these collisions), and the aggressivity of vehicles in VRU collisions.

## 6.5. Further research and knowledge generation

This research has extended understanding of the environmental ingredients in fatal crashes on New Zealand roads. To further this understanding, research using a wider range of data and methods is also needed.

Moving beyond a Safe System view of crashes, a sociotechnical approach should be taken to gain a broader view of the determinants of crashes as identified earlier in Section 3.2. This involves not only an account of the speed, road, vehicle, and road user conditions, but also an upstream view of the practices, policies, and societal conditions that ultimately allow a safe road system to be delivered, or not. Sociotechnical analyses have already been carried out for work-related road safety [7], and cycling fatalities in New Zealand [24], and the 'fatal five' behaviours for road trauma in Queensland, Australia [23].

With sufficient data and subject matter input, these analyses can explicitly illustrate policies and practices that are likely to lead to a reduction in road safety risk.

Building on a limitation of this research, developing a better understanding of 'very serious crashes' using ACC data to identify relevant crashes, would allow in-depth analyses of the most severe crashes (fatal and 'very serious'), while not flooding the data with crashes that are of much lower severity, and may have quite different characteristics. Definitions, protocols, and organisational arrangements would need to be established with the appropriate government agencies.

Future in-depth research seeking to gain a more in-depth understanding of key issues and associated potential solutions can be initiated from this data/research. Seatbelt use, drugs, the speed/infrastructure interaction, and vehicle contributions are all areas that have emerged as being important from the present research and would benefit from further interrogation. Most importantly, interactions between system factors in real-life contexts should be examined, so that interventions could be prioritised to act as circuit breakers, preventing fatal crashes.

Other areas that have not been addressed in this research, but are ultimately important for safe road use, include:

- **Post crash care –** factors that determine survivability following a crash.
- **Equity and road safety –** who is disproportionately affected by road crashes? Why?
- **What went right? –** what situations led to the avoidance of a fatal or very serious crash. Contemporary health and safety practices and research tend to focus on the conditions that ultimately mean people remain safe and well, with thriving and productive workplaces being contiguous with safety practices. In road safety, what road conditions lead to thriving, productive, and safe communities?
- **Evaluations, trialling, and modelling of road safety initiatives –** what initiatives are likely to make the most difference based on innovation, iterative design, and evaluation? There is currently a degree of investment 'lock-in' within road safety, facilitated by large scale programmes, investment cases, and assumed theory. However, despite the confidence projected in many business cases, in reality, the outcome from any investment is unknown. Better modelling, trials, and evaluations are needed to gain confidence in investments, reduce investment risk, and avoid poor spending. The development, trialling, and evaluation of Intersection Speed Zones is a good example.

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# Appendix A: Literature Scan Search Strategy and Terms

### *Search strategy*

The scan was limited to system analyses of fatal crashes,[10] as well as relevant sociotechnical and system mapping analyses. The search terms described in Appendix A were used to complete a search for relevant papers in the Google Scholar database. Additional relevant projects completed by Mackie Research were also included. Snowballing using the reference lists of relevant papers was conducted to identify further pertinent research to be included.

To identify any grey literature and to ensure that the scan had considered the work of the most relevant research and government institutions, a specific search of databases at the following organisations was completed:

- New Zealand Transport Agency and Ministry of Transport
- Monash University Accident Research Centre (Australia)
- National Highway Traffic Safety Authority (United States)
- Swedish National Road and Transport Research Institute (VTI)
- Department for Transport (UK)

### *Literature scan review process*

Upon confirmation of its relevance, each document was sourced and stored electronically. The paper was also imported into Mendeley for ease of reference management. A list of all the papers cited in this review is provided above.

### *Search terms*

- System analysis of fatal crashes
- Safe System analysis of fatal crashes
- System mapping of fatal crashes
- Sociotechnical analysis of fatal crashes
- Determinants of fatal crashes
- Contributing factors to fatal crashes
- System determinants of fatal crashes

[10] Although this analysis is focused on fatal crashes, previous analyses have been conducted for to include or are solely focused on serious injury crashes. These remain relevant to this work, although there are differences in the characteristics of these crash types, with fatal crashes typically involving multiple system failures, or extreme behaviour.

# Appendix B: Cluster Analysis Further Detail

### *Multiple Correspondence Analysis*

Multiple correspondence analysis (MCA) was applied to the variables selected for inclusion in the cluster analysis. This was used to apply a numerical transformation on categorical variables allowing the cluster analysis to be conducted on the MCA.

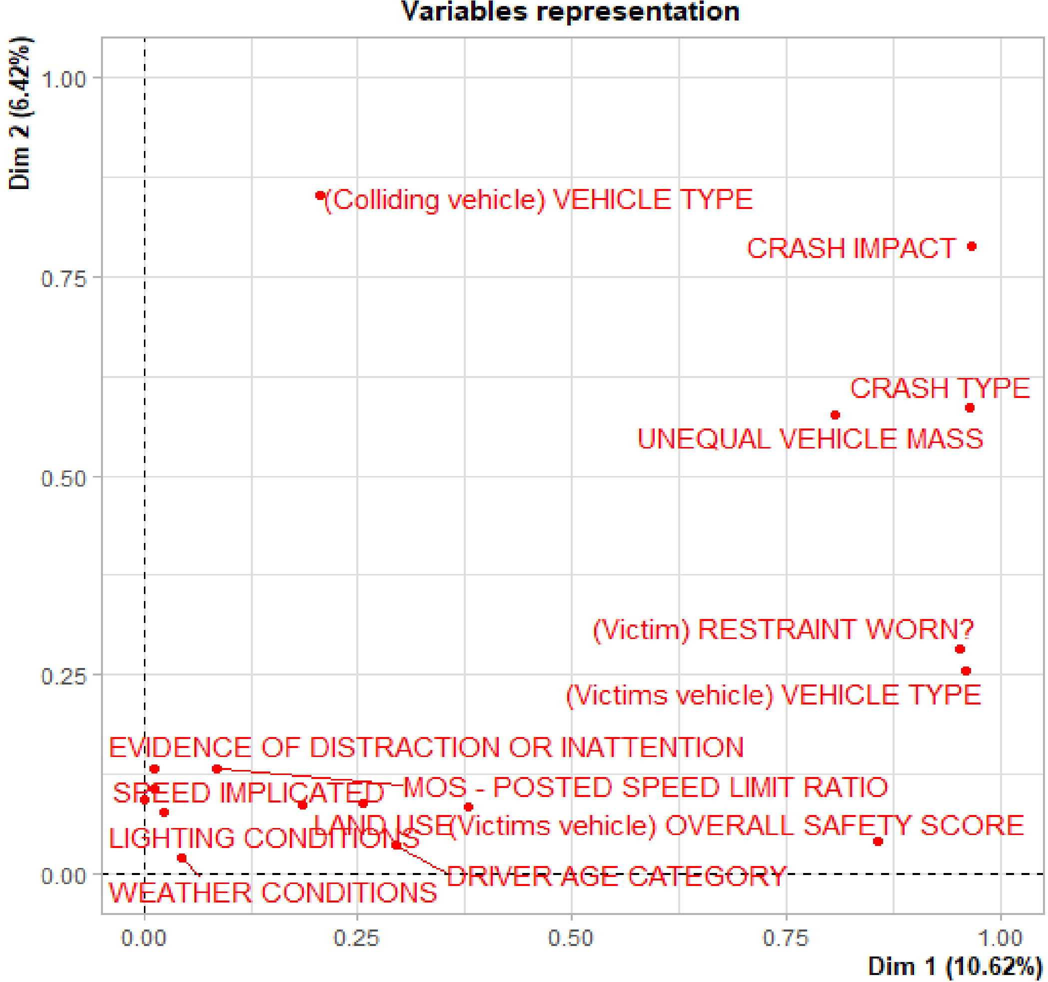


*Figure 36: Output of the multiple correspondence analysis.*

Overall, this MCA explains a moderate proportion of the total variation (17%) across the categorical variables (Figure 36). This level of explained variation is typical for MCAs with a moderate number of variables and many category levels, where inertia naturally disperses across dimensions. Dimension 1 primarily reflects patterns related to road-user and crash-type characteristics, capturing differences in vehicle type, mass mismatch, and crash configuration. Dimension 2 is mainly driven by collision dynamics and impact-related factors, differentiating crashes by impact type and striking-vehicle characteristics. Other variables contribute less to the first two dimensions but still support the interpretation of cluster differences and add context to the overall pattern.

### *Hierarchical Clustering*

Figure 37 shows the cluster dendrogram, displaying how the clusters were formed from the MCA with the height at which the branches join showing how similar the clusters are. For example, the main divide occurred early separating vehicle crashes from crashes where a vehicle collided with a VRU, and smaller differences exist between the crashes involved in the subgroups subsequently formed.

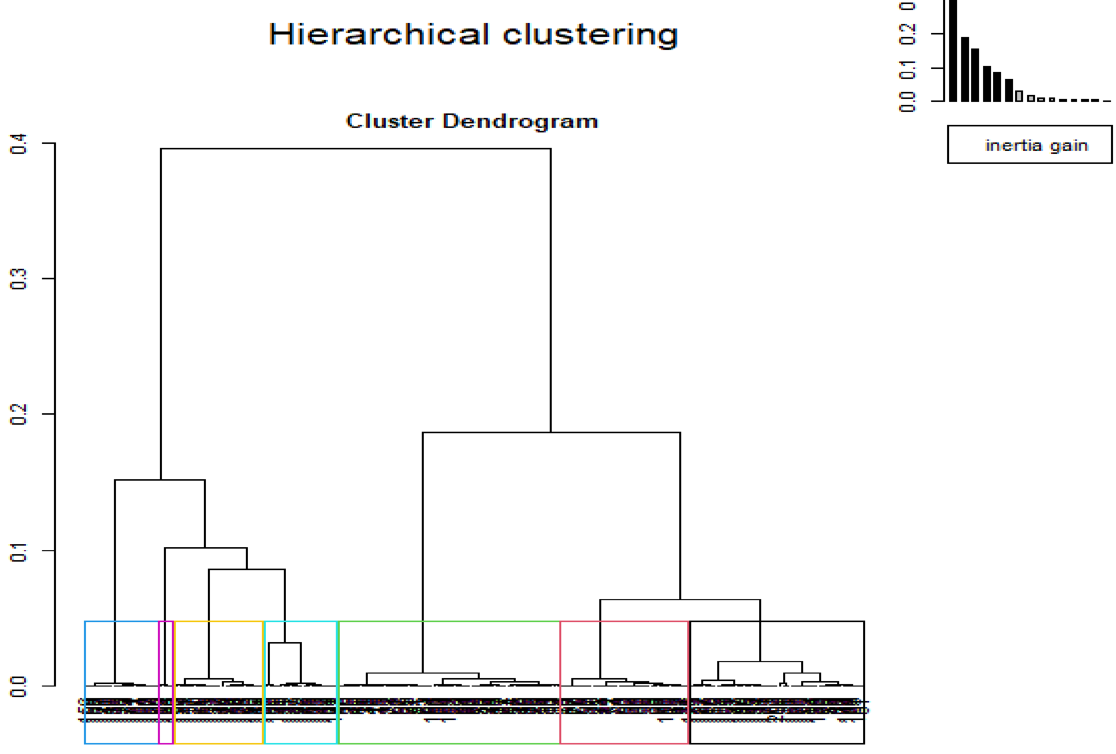


*Figure 37: Hierarchical cluster dendrogram.*

Figure 38 displays the factor map which shows the location of the sample fatal crashes in relation to each other, coloured by the cluster they are associated with. The final cluster map is shown in Figure 31 in Section 5.

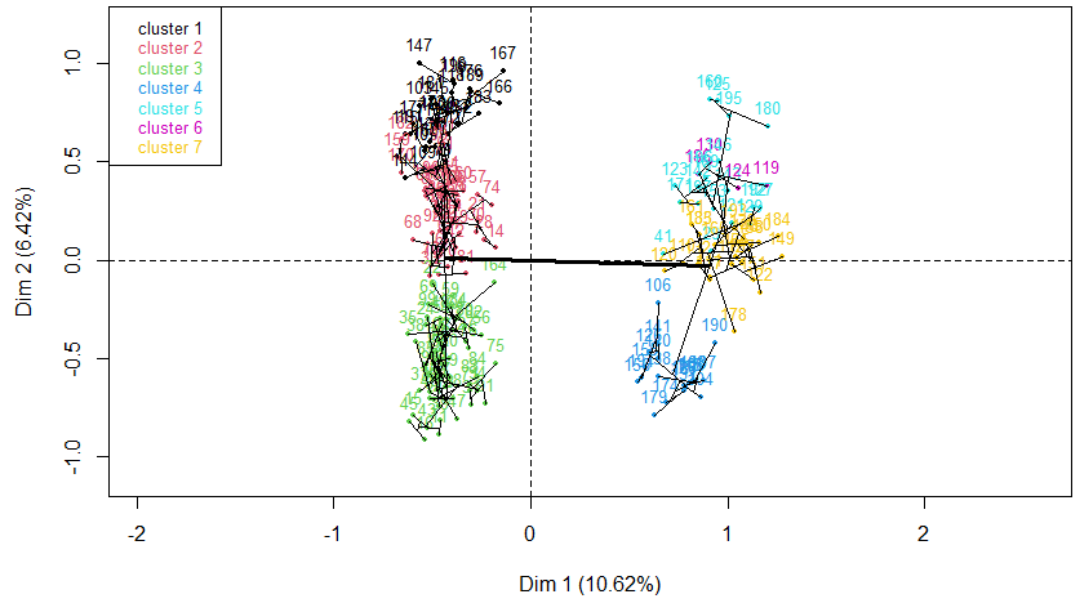


*Figure 38: Hierarchical clustering factor map.*

### *Non-Hierarchical Clustering*

As described in the methods, a validation exercise was conducted to confirm that the clusters developed were valid and robust. Figure 39 displays the cluster plot developed through non-hierarchical clustering using the k-means method. The clusters formed by the two methods were identical, indicating that they are valid.

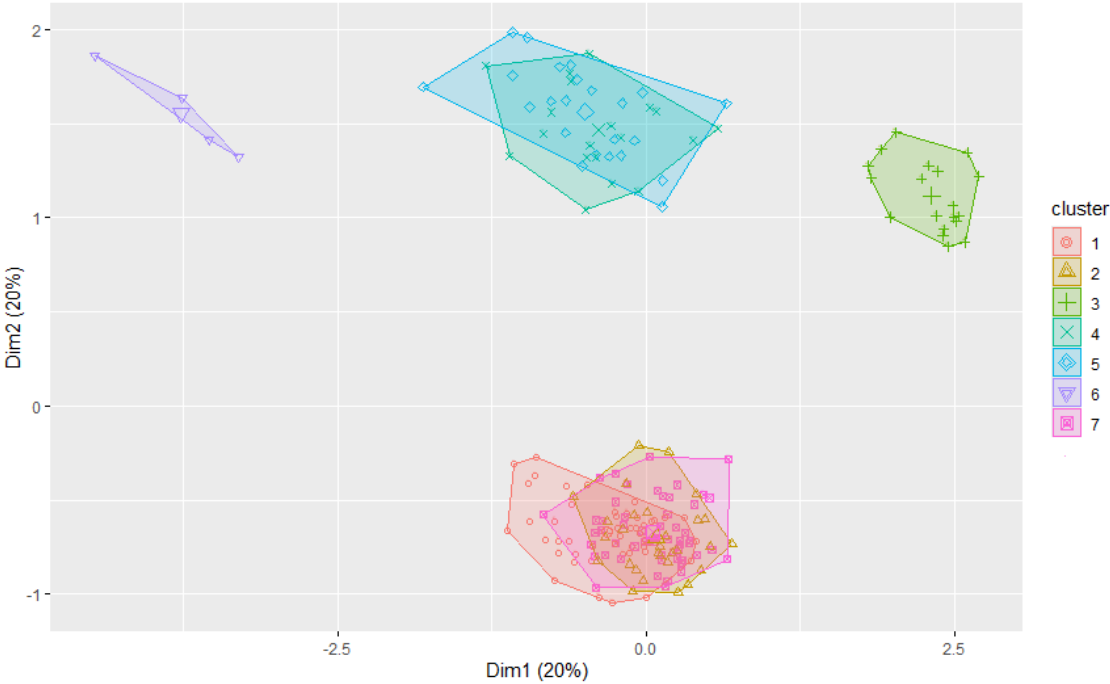


*Figure 39: Cluster plot for the non-hierarchical (k-means) clustering method.*

Even though both the hierarchical and k-means methods grouped the crashes into the same clusters, the clusters appear in different places on the two cluster maps because the maps are created using different dimension-reduction techniques. These techniques condense many variables down into two axes so the data can be plotted, but the resulting picture doesn't have a fixed orientation. The whole plot can rotate, flip, or shift without changing the underlying relationships between the points. Therefore, although the clusters themselves are consistent and valid, the diagrams don't look identical because each method produced its own version of the two-dimensional layout.